Chapter 3A: Water Quality in the Everglades Protection Area

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SUMMARY

This chapter is intended to (1) provide an assessment of water quality within the Everglades Protection Area (EPA) during Water Year 2015 (WY2015) (May 1, 2014–April 30, 2015), (2) fulfill numerous reporting requirements of the Everglades Forever Act (EFA), (3) provide a preliminary assessment of total phosphorus (TP) criterion achievement, and (4) provide an annual update of the comprehensive overview of nitrogen and phosphorus concentrations and loads throughout the EPA. The information provided in this chapter is an update to Chapter 3A of the *2015 South Florida Environmental Report* (SFER) – *Volume I*.

WATER QUALITY CRITERIA EXCURSION ANALYSIS

The analyses and summaries presented provide a synoptic view of water quality conditions in the EPA on a regional scale, including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge, also known as WCA-1), Water Conservation Areas 2 and 3 (WCA-2 and WCA-3, respectively), and Everglades National Park (ENP or Park). For parameters with water quality criteria, regional analyses were conducted based on the frequency of exceedances of the applicable criteria, similar to the methods employed in the 1999 Everglades Interim Report, 2000–2004 Everglades Consolidated Reports, and 2005–2015 SFERs. For WY2015, water quality parameters that did not meet existing standards were classified based on excursion frequencies that were statistically tested using the binomial hypothesis test. These categories are (1) concern – any parameter with a criterion exceedance frequency statistically greater than 10 percent, (2) potential concern – any parameter with an exceedance frequency statistically greater than 5 percent but less than 10 percent, and (3) minimal concern – any parameter with an exceedance frequency less than 5 percent but greater than zero.

Similar to the last several years with a few exceptions, water quality was in compliance with existing state water quality criteria during WY2015. During WY2015, excursions of applicable Class III water quality criteria were observed for four parameters: dissolved oxygen (DO), alkalinity, pH, and specific conductance. Similar to previous periods, these excursions were localized to specific areas of the EPA, and all these parameters exhibited excursions in previous water years.

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For WY2015, a summary of the DO, alkalinity, pH, specific conductance, and un-ionized ammonia excursions, as well as the status of pesticides, phosphorus, and nitrogen within the EPA, is presented below.

- Due to excursions of the site-specific alternative criterion, DO was classified as a potential concern for the interior portion of the Refuge, WCA-2 and WCA-3, and ENP. Inflow, outflow, and Rim Canal monitoring locations were assessed using the current Class III water quality standard. Inflow portions of the Refuge, WCA-3, and ENP as well outflow portions of WCA-2 and WCA-3 were classified as a concern, Refuge outflow and WCA-2 inflow were classified as a minimal concern, and the Refuge rim portion was classified as no concern.
- Alkalinity and pH criteria exceedances were observed in the Refuge; however, the Florida Department of Environmental Protection (FDEP) considers the relatively low values to be representative of the range of natural conditions for this ecosystem. Therefore, they are not considered violations of state water quality standards. Exceedances of the pH criterion resulted in areas and regions being classified as a minimal concern, including WCA-2 and WCA-3 inflow regions.
- Specific conductance was categorized as a minimal concern for the Refuge inflow and rim regions as well as WCA-2 inflow region.
- Unionized ammonia was categorized as a minimal concern for WCA-2 inflow region.
- No exceedances of iron or turbidity were observed in the EPA.
- No pesticides or pesticide breakdown products exceeded their respective toxicity guideline concentrations, and no parameters exceeded state water quality standards. However, several pesticides or pesticide breakdown products were detected at levels above their method detection limit, including 2,4,5-T (Trichlorophenoxyacetic acid), 2,4-D, ametryn, atrazine, atrazine desethyl, diuron, imidacloprid, metolachlor, metribuzin, norflurazon, and silvex.
- TP concentrations were highest in WCA-3 inflows and lowest within the Park. Annual geometric mean inflow TP concentrations ranged from 9.0 µg/L micrograms per liter (µg/L) for the Park to 22.5 µg/L for the WCA-3. Annual geometric mean TP concentrations at interior regions ranged from 4.1 µg/L in the Park to 9.0 µg/L in the Refuge. Annual geometric mean TP concentrations for individual interior marsh monitoring stations ranged from less than 2.0 µg/L in some unimpacted portions of the marsh to 107.0 µg/L at sites that are highly influenced by canal inputs. Of the interior marsh sites, 71.7 percent exhibited annual geometric mean TP concentrations of 10.0 µg/L or less, with 85.6 percent of the marsh sites having annual geometric mean TP concentrations of 15.0 µg/L or less throughout the larger ambient monitoring network.
- Annual geometric mean inflow orthophosphate (OP) concentrations ranged from less than 2.0 µg/L for the Park to 2.0 µg/L for WCA-3. The annual geometric mean interior OP concentrations for all regions of the EPA were less than 2.0 µg/L.
- Similar to previous years' reporting, the five-year (WY2011–WY2015) TP criterion assessment results indicate that unimpacted portions of each WCA passed all four parts of the compliance test. In contrast, impacted portions of each water body failed one or more parts of the test. The impacted portions of the WCAs routinely exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively.
- TP loads from surface sources, including internal transfers within the EPA, totaled approximately 65.2 metric tons (mt), with a flow-weighted mean concentration (FWM)

of 17 µg/L. Another 193 mt of TP are estimated to have entered the EPA through atmospheric deposition. The 65.2 mt TP load in the surface inflows to the EPA represents a decrease of approximately 25 percent compared to the previous year (87.1 mt in WY2014).

- Annual geometric mean inflow total nitrogen (TN) concentrations ranged from 1.01 mg/L for the Park to 1.75 mg/L for the Refuge. The annual geometric mean TN concentration at interior marsh regions ranged from 1.02 mg/L for the Park 1.55 mg/L for WCA-2.
- TN loads from surface sources, including internal transfers within the EPA totaled approximately 6,458 mt, with a FWM concentration of 1.77 mg/L. Another 4,664 mt of TN are estimated to have entered the EPA through atmospheric deposition. The 6,458 mt TN load in the surface inflows to the EPA represent a decrease of approximately 20 percent compared to the previous year (6,458 mt in WY2014).

PURPOSE

The primary purpose of this chapter is to provide an assessment of water quality within the Everglades Protection Area (EPA) during Water Year 2015 (WY2015) (May 1, 2014–April 30, 2015) and an update to the information provided in Chapter 3A of the *2014 South Florida Environmental Report* (SFER) – *Volume I*.

The chapter is intended to fulfill the Everglades Forever Act (EFA) requirement for an annual report to "identify water quality parameters, in addition to phosphorus, which exceed state water quality standards or are causing or contributing to adverse impacts in the Everglades Protection Area." In addition, this chapter provides an annual update of the comprehensive overview of nitrogen and phosphorus concentrations and loads throughout the EPA, along with an assessment of total phosphorus (TP) criterion achievement utilizing the protocol provided in the 2007 SFER – Volume I, Chapter 3C.

More specifically, this chapter and its associated appendices use water quality data collected during WY2015 to achieve the following objectives:

1. Summarize areas and times where water quality criteria are not being met and indicate trends in excursions over space and time.
2. Discuss factors contributing to excursions from water quality criteria and provide an evaluation of natural background conditions where existing standards may not be appropriate.
3. Present an updated review of pesticide and priority pollutant data made available during WY2015.
4. Present a preliminary TP criterion achievement assessment for different areas within the EPA for the most recent five-year period (WY2011–WY2015).
5. Summarize phosphorus and nitrogen concentrations measured in surface waters within different portions of the EPA.
6. Summarize the flow and phosphorus loads entering different portions of the EPA and describe spatial and temporal trends observed.
7. Describe and discuss factors contributing to any spatial and temporal trends observed.

METHODS

A regional synoptic approach similar to that used for water quality evaluations in previous SFERs was applied to phosphorus and nitrogen data for WY2015 to provide an overview of water quality status within the EPA. Consolidating regional water quality data provides the ability to analyze data over time but limits spatial analyses within each region. However, spatial analyses can be made between regions because the majority of inflow and pollutants enter the northern third of the EPA, and the net water flow is from north to south.

AREA OF INTEREST

The EPA is a complex system of marsh areas, canals, and levees with inflow and outflow water control structures that covers almost 2.5 million acres (1 acre = 0.405 hectare) of former Everglades marsh and currently is divided into large separate distinct shallow impoundments (Bancroft et al., 1992). In addition to rainfall inputs, surface water inflows regulated by water control structures from agricultural tributaries, such as the Everglades Agricultural Area (EAA) to the north and the C-139 basin to the west, feed the EPA. The EPA also receives surface water inflows originating from Lake Okeechobee to the north and from predominantly urbanized areas to the east. The timing and distribution of the surface inflows from the tributaries to the EPA are based on a complex set of operational decisions that account for natural and environmental system requirements, water supply for urbanized and natural areas, aquifer recharge, and flood control. The major features of the EPA and surrounding area are illustrated in Figure 1-1 of this volume.

WATER QUALITY SAMPLING STATIONS IN THE EPA

To efficiently assess annual water quality standard violations and long-term trends, a network of water quality sampling sites has been identified (**Figures 3A-1** through **3A-4**). These sites are part of the South Florida Water Management District's (SFWMD or District) long-term monitoring projects and are monitored for different purposes. These stations were carefully selected to be representative of either the EPA boundary conditions (i.e., inflow or outflow) or ambient marsh conditions (interior). Furthermore, an effort has been made to utilize a consistent group of stations among previous annual consolidated reports to ensure consistent and comparable results. As the naming convention for monitoring stations within the EPA has changed throughout the progression of the monitoring periods, Appendix 3A-1, Table 2, provides cross-reference table for each stations identifier.

Water quality sampling stations located throughout the Water Conservation Areas (WCAs) and Everglades National Park (ENP or Park) were categorized as inflow, interior, or outflow stations within each region based on their location and function (**Figures 3A-1** through **3A-4**). This organization of monitoring sites allows a more detailed analysis of the water quality status in each region of the EPA and assists in the evaluation of potential causes for observed excursions from Class III water quality criteria.

Several interior structures convey water between different regions in the EPA and therefore are designated as both inflow and outflow stations based on this categorization system. For example, the S-10 structures act as both outflow stations for the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge, also known as WCA-1) and inflow sites to Water Conservation Area 2 (WCA-2) (**Figures 3A-1** and **3A-2**). The interior sites of each region consist of marsh and canal stations as well as structures that convey water within the area.

In addition to inflow, outflow, and interior sites, the Refuge has a category for Rim Canal sites to account for water entering the Refuge interior from canals that border the east and west levees of the Refuge (**Figure 3A-1**). Waters discharged to the L-7 Rim Canal will either overflow into the

Refuge interior when canal stages exceed the ground elevation or will bypass the marsh and be discharged to WCA-2A through the S-10 structures. The extent (distance) to which Rim Canal overflows penetrate the marsh depends on the relative stages of the L-7 and L-40 Rim Canal and the Refuge interior.

Sampling frequency varies by site depending on site classification, parameter group, and hydrologic conditions (e.g., water depth and flow). Water control structures (inflows and outflows) were typically sampled biweekly when flowing; otherwise, sampling was performed monthly. Generally, interior monitoring stations were sampled monthly for most parameters reported in this chapter. Pesticide monitoring is conducted across the entire District at 15 sites on a biannual basis. An overview of the water quality monitoring projects, including project descriptions and objectives with limited site-specific information, is available on the District's website at www.sfwmd.gov/environmentalmonitoring.

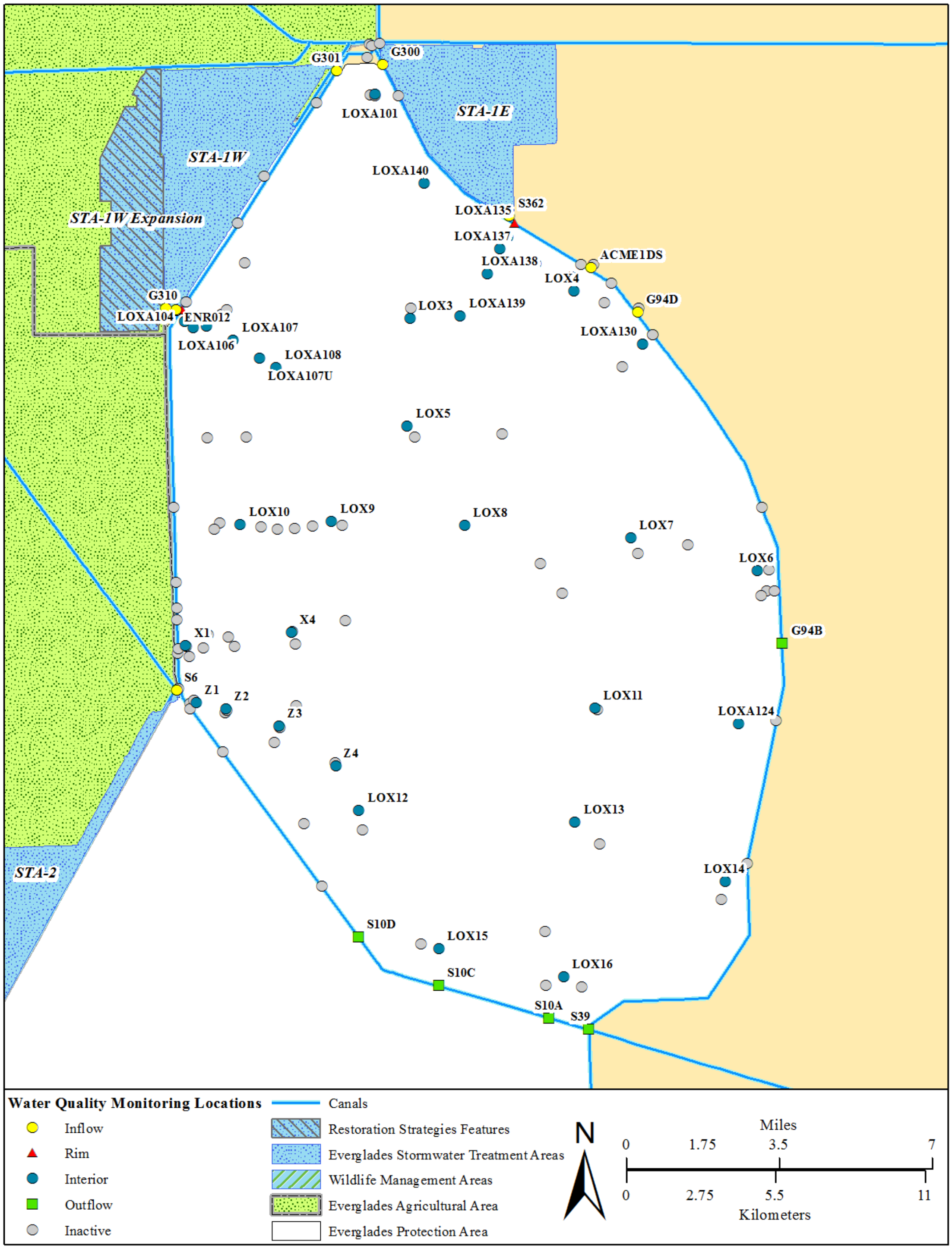

Figure 3A-1. Location and classification of water quality monitoring stations in the Water Conservation Area 1 (WCA-1)/Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). [Note: Stations G300 and G301 located north of the Refuge are diversion structures and rarely exhibit flow into the Refuge.]

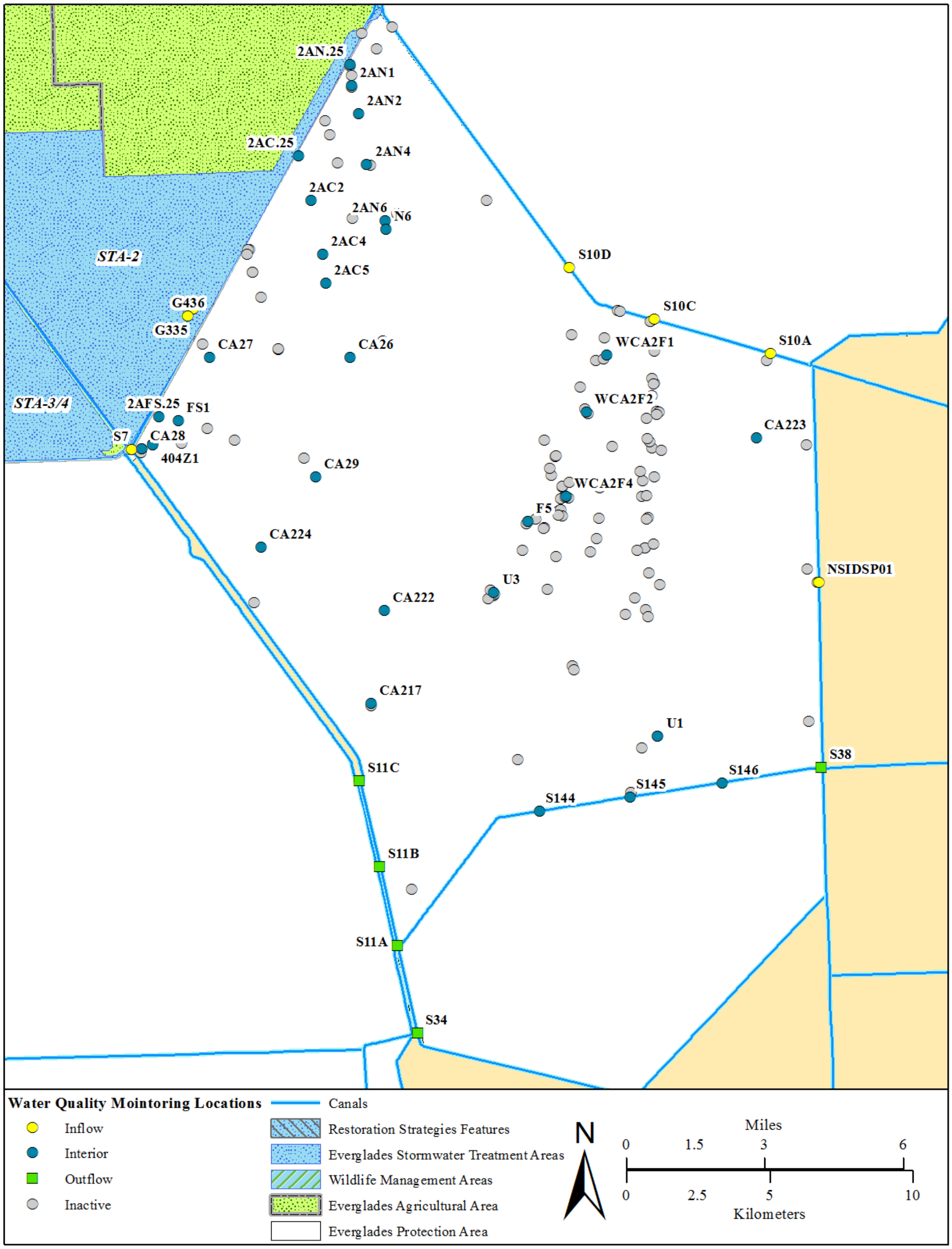

Figure 3A-2. Location and classification of water quality monitoring stations in Water Conservation Area 2 (WCA-2).

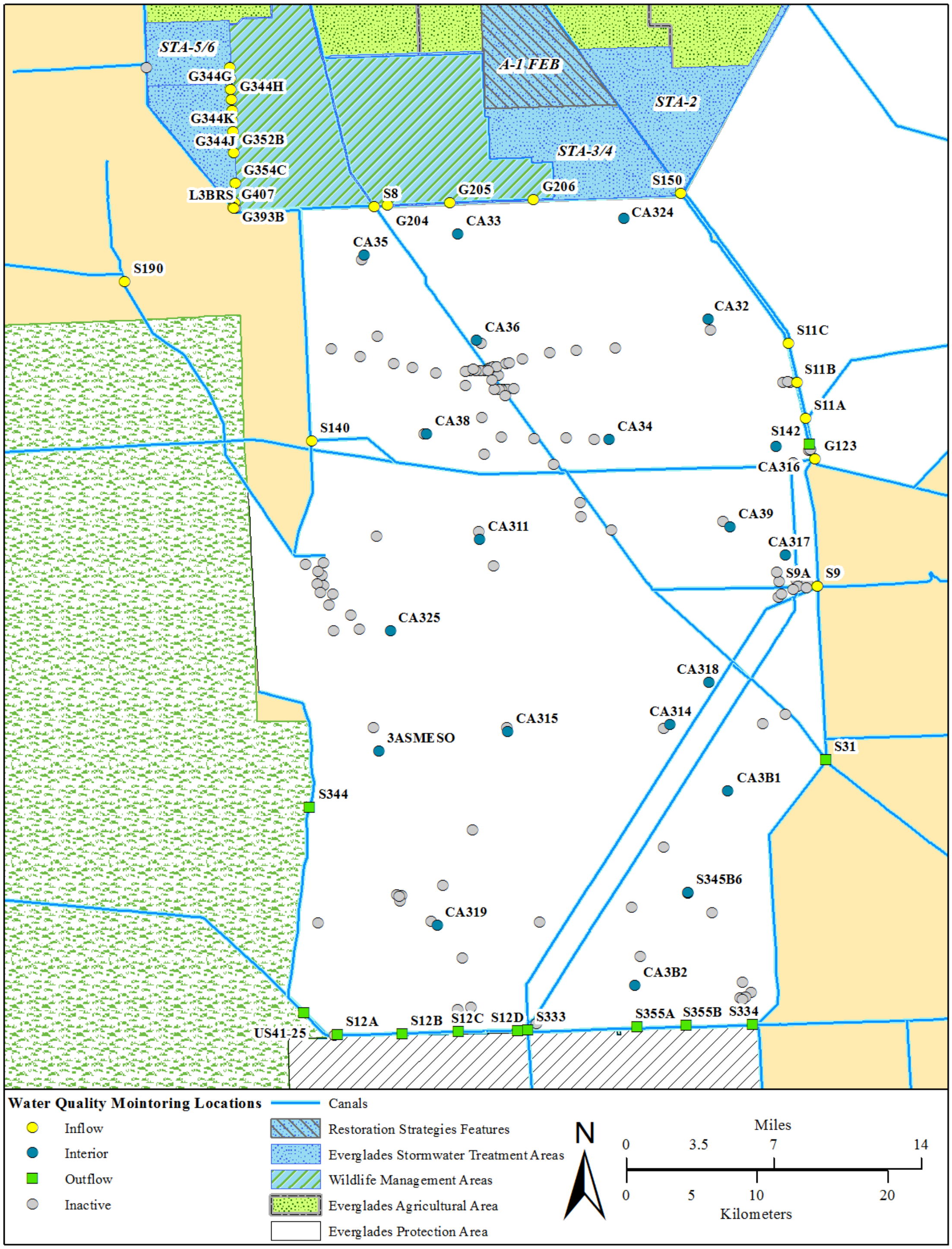

Figure 3A-3. Location and classification of water quality monitoring stations in Water Conservation Area 3 (WCA-3).

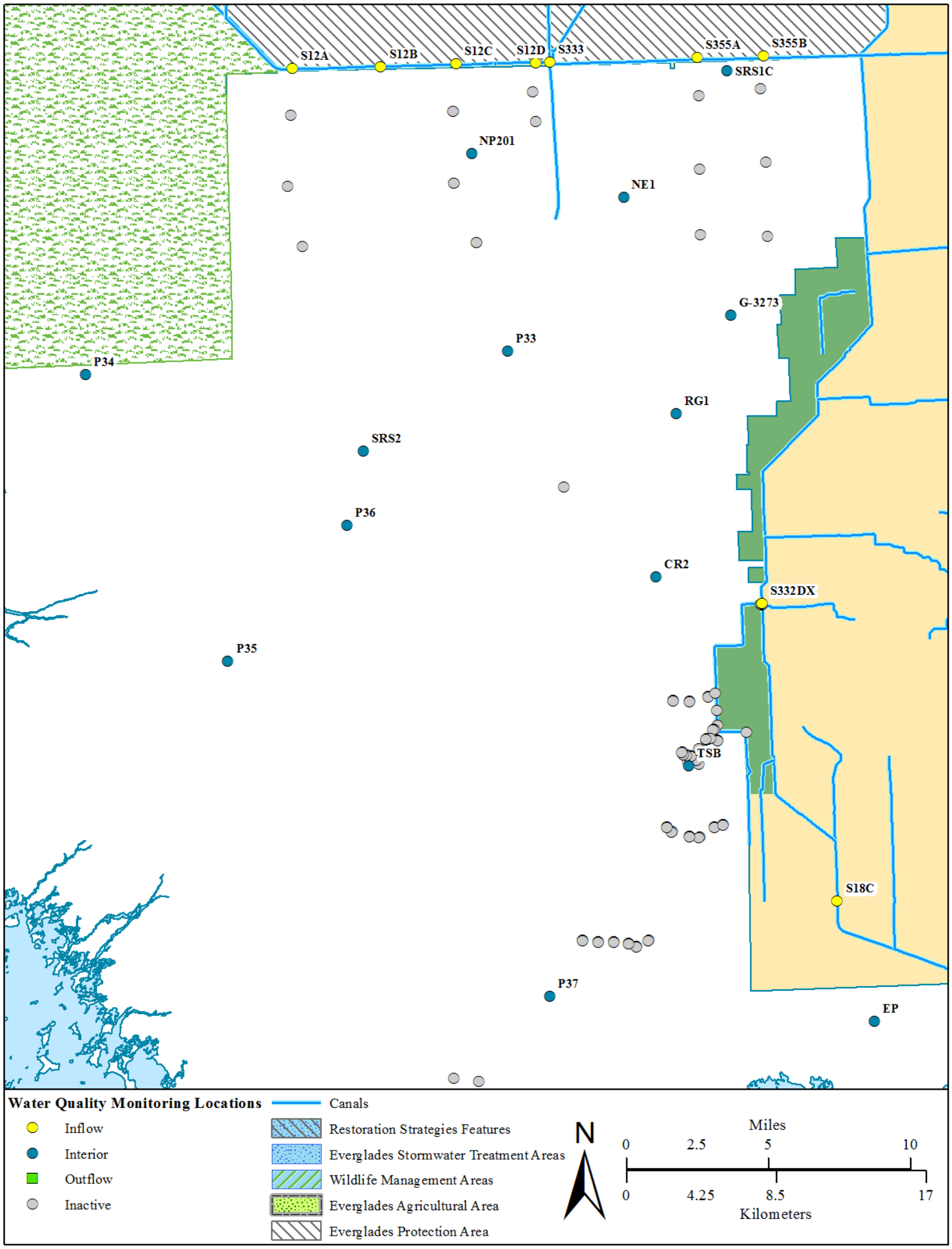

Figure 3A-4. Location and classification of water quality monitoring stations in Everglades National Park (ENP or Park).

ANALYSIS PERIODS

As previously noted, the primary focus of this chapter is to summarize the status of water quality within the EPA during WY2015 and describe trends or changes in water quality conditions over time. To accomplish this objective, comparisons are made across discrete periods that correspond to major restoration activities occurring within the EPA. The four periods are (1) the historical WY1979–WY1993 period (Baseline), which corresponds to the timeframe prior to implementation of the EAA Best Management Practices (BMPs) Program and the Everglades Construction Project (i.e., Everglades Nutrient Removal Project/Everglades Stormwater Treatment Areas, or STAs), (2) the intermediate WY1994–WY2004 period (Phase I), (3) the Phase II BMP/STA implementation period after WY2004 (i.e., WY2005–WY2014), and (4) the current water year, WY2015.

Phase I represents the period in which implementation of the EAA BMP Program was increasing, and all the initial STAs were constructed and became operational. The Phase II BMP/STA implementation period corresponds to when the performance of the BMPs and STAs were being optimized and enhanced. Additionally, during this period various restoration projects were being implemented under the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan)(Miller, 2003), Restoration Strategies Regional Water Quality Plan (SFWMD, 2012), Comprehensive Everglades Restoration Plan (CERP) (USACE and SFWMD, 1999), and other state or federal restoration projects. Because optimization, enhancement, and other restoration activities are expected to continue for years, the Phase II period will continue to expand in future SFERs to incorporate additional years of sampling. In addition, data for the current water year (WY2015) will be used to make comparisons with the historical periods and will be analyzed independently as the fourth period. Individual station assessments and certain mandated reporting (e.g., TP criterion achievement) were based on the previous five water years (WY2011–WY2015) rather than on the single year used for regional analysis. Reporting periods are specified in each section of this chapter.

WATER QUALITY DATA SOURCES

The majority of the water quality data evaluated in this chapter were retrieved from the District's DBHYDRO database (www.sfwmd.gov/dbhydro). Additionally, water quality data from the nutrient gradient sampling stations monitored by the District were obtained from the District's Water Resources Division database.

DATA SCREENING AND HANDLING

Water quality data were screened based on laboratory qualifier codes, consistent with the Florida Department of Environmental Protection (FDEP) Quality Assurance Rule [Chapter 62-160, Florida Administrative Code (F.A.C.)]. Any datum associated with a fatal qualifier (e.g., H, J, K, N, O, V, Q, Y, or ?) indicating a potential data quality problem was removed from the analysis (SFWMD, 2015). Values that exceeded possible physical or chemical measurement constraints (e.g., if resulting pH is greater than 14) had temperatures well outside seasonal norms (e.g., 6 degrees Celsius in July) or represented data transcription errors were excluded. Multiple samples collected at the same location on the same day were considered as one sample, with the arithmetic mean used to represent the sampling period.

Additional considerations in the handling of water quality data are the accuracy and sensitivity of the laboratory method used. For purposes of summary statistics presented in this chapter, data reported as less than the method detection limit (MDL) were assigned a value of one-half the MDL unless otherwise noted. All data presented in this chapter, including historical results, were handled consistently with regard to screening and MDL replacement.

WATER QUALITY DATA PARAMETERS

The District monitors 109 water quality parameters within the EPA (Payne and Xue, 2012). Given this chapter's focus on water quality criteria, the evaluation was primarily limited to parameters with Class III criteria pursuant to the FDEP's Surface Water Quality Standards Rule (Chapter 62-302, F.A.C.). The parameters evaluated in this chapter include 62 pesticides and the following water quality constituents:

- Alkalinity
- Dissolved oxygen (in situ)
- Specific conductance (in situ)
- pH (in situ)
- Total selenium*
- Total thallium*
- Total zinc*
- Turbidity
- Un-ionized ammonia
- Sulfate
- Total nitrogen
- Total cadmium*
- Total iron
- Total lead*
- Total nickel*
- Total silver*
- Total antimony*
- Total arsenic*
- Total beryllium*
- Total copper*
- Total phosphorus
- Orthophosphate

Parameters marked with an asterisk (*) were not measured in WY2015. However, these have been analyzed and reported in previous SFERs and, if measured in the future, will be analyzed and reported in future SFERs.

WATER QUALITY CRITERIA EXCURSION ANALYSIS

The FDEP and the District have developed an excursion analysis protocol for use in the annual SFER (Weaver and Payne, 2005) to effectively provide a synoptic view of water quality criteria compliance on a regional scale [i.e., the Refuge, WCA-2, Water Conservation Area 3 (WCA-3), and the Park]. The protocol was developed to balance consistency with previous versions of the report, other State of Florida ambient water quality evaluation methodologies [e.g., Impaired Waters 303(d) designations], and the United States Environmental Protection Agency (USEPA) exceedance frequency recommendations, as well as provide a concise summary for decision makers and the public. This methodology ensures results will be compatible with information from other sources provided to water managers.

A multi-tiered categorical system was used in this chapter to rank the severity of excursions from state water quality criteria (see **Table 3A-2**). Categories were assigned based on sample excursion frequencies evaluated using a statistically valid assessment methodology (i.e., binomial hypothesis test) that accounted for uncertainty in monitoring data (Weaver and Payne, 2005). Parameters without exceedances were categorized as no concern (NC) and are not discussed further in this chapter. Based on the results of the binomial test using a 90 percent confidence level, parameters with exceedance rates between 0 and 5 percent are classified as minimal concerns (MC), those with exceedance rates between 5 and 10 percent are classified as potential concerns (PC), and those with exceedance rates greater than 10 percent are classified as concerns (C).

Because exceedances of the pesticide criteria can result in more immediate and severe effects to aquatic organisms and human health, a 10 percent excursion frequency was not used in the assessment of pesticides as recommended by the USEPA (USEPA, 1997; 2002). Pesticides were evaluated under the assumption that the Class III criteria values represent instantaneous maximum concentrations for which any exceedance constitutes a non-attainment of designated use. Pesticides were categorized based on whether the parameter was detected at concentrations above the MDL (potential concern) or at concentrations exceeding Class III criteria or chronic toxicity values (concerns). Pesticides classified as concerns have a high likelihood of resulting in an impairment of the designated use of the water body. Classification of a pesticide as a potential concern signifies that the constituent is known to be present within the basin at concentrations reasonably known to be below levels that can result in adverse biologic effects but may result in a problem at some future date or in interaction with other compounds. The no concern category was used to designate pesticides that were not detected at sites within a given area.

The data sources as well as the data handling and evaluation methods employed in this chapter are identical to those used in previous SFERs. Greater detail concerning the methods used can be found in Weaver and Payne (2005) and Payne and Xue (2012).

PHOSPHORUS CRITERION ACHIEVEMENT ASSESSMENT

An evaluation to determine achievement of the TP criterion was performed consistent with assessment protocol presented by Payne et al., (2007), and the four-part test outlined below and specified in the FDEP's Water Quality Standards for Phosphorus within the Everglades Protection Area (Chapter 62-302.540, F.A.C.). Achievement of the TP rule (i.e., 62-302.540 FAC) is assessed for networks of impacted and unimpacted, spatially explicit monitoring locations in WCAs (i.e., WCA-1/Refuge, WCA-2, and WCA-3). Achievement of the P criterion is different for Everglades National Park than the established TP criterion for the EPA. As acknowledged by 62-302.530(4)(c) achievement of the TP criterion is assessed according to methods set forth in Appendix A of the Settlement Agreement (Hoeveler, 1988) until the Settlement Agreement is amended or terminated. Reports and supporting information related to TP assessments consistent with Appendix A of the Settlement Agreement can be found at http://www.sfwmd.gov/toc.

Achievement of the TP criterion is assessed by a four-part test for each WCA using two networks of stations; impacted and unimpacted. The parts of the achievement test are:

1. The five-year geometric mean averaged across all stations is less than or equal to 10 µg/L.
2. The annual geometric mean averaged across all stations is less than or equal to 10 µg/L for three of five water years.
3. The annual geometric mean averaged across all stations is less than or equal to 11 µg/L; and
4. The annual geometric mean at all individual stations is less than or equal to 15 µg/L.

Data from the 58 sites TP criterion monitoring network for the most recent five-year period (i.e., WY2011–WY2015) were utilized in the evaluation. The location of the TP criterion network monitoring sites established pursuant to the TP criterion rule used for the TP criterion assessment along with their classification as "impacted" or "unimpacted" are provided in **Figure 3A-5**. Details concerning the selection of sites in the TP criterion monitoring networks and their classification can be found in Payne et al. (2007) and Julian (2015).

Data collection from the complete TP criterion monitoring network was initiated in January 2007. Due to the relatively recent inception of network monitoring, not all sites have data available for the full five-year assessment period. In addition, data availability is further limited for certain portions of the EPA due to extremely dry conditions that have prevailed during a number of years since WY2007. Because the results of the TP criterion compliance assessment presented in this chapter could be affected by these data limitations, this evaluation should be considered preliminary and the results cautiously interpreted. It is expected that future assessments will improve as additional datasets are added. Data were screened according to the QA/QC procedures described in the protocol on the FDEP's website at http://www.dep.state.fl.us/everglades/files/criterion_ScreeningProtocol.pdf or http://www.dep.state.fl.us/water/wqssp/docs/swqdocs/data-quality-screening-protocol.pdf

STATISTICAL ANALYSIS

Unless otherwise noted all inflow and outflow summary statistics (geometric mean, minimum, maximum, etc.) were performed using data collected on flow events only. All valid data (i.e., non-qualified data) were used to compute summary statistics for all other regions (i.e., interior and rim). Trend analysis was performed on annual geometric mean TP and total nitrogen (TN) concentrations for inflow and interior regions of the EPA using the Kendall's τ correlation analysis (Base stats R package) and Sen's slope estimate (zyp R package). Trend analysis was performed on annual geometric mean TP for each monitoring station, with greater than three years of data using Kendall's τ correlation analysis and Sen's slope estimate. All statistical operations were performed with R© (Ver 3.1.2, R Foundation for Statistical Computing, Vienna Austria). The critical level of significance was set at $\alpha = 0.05$.

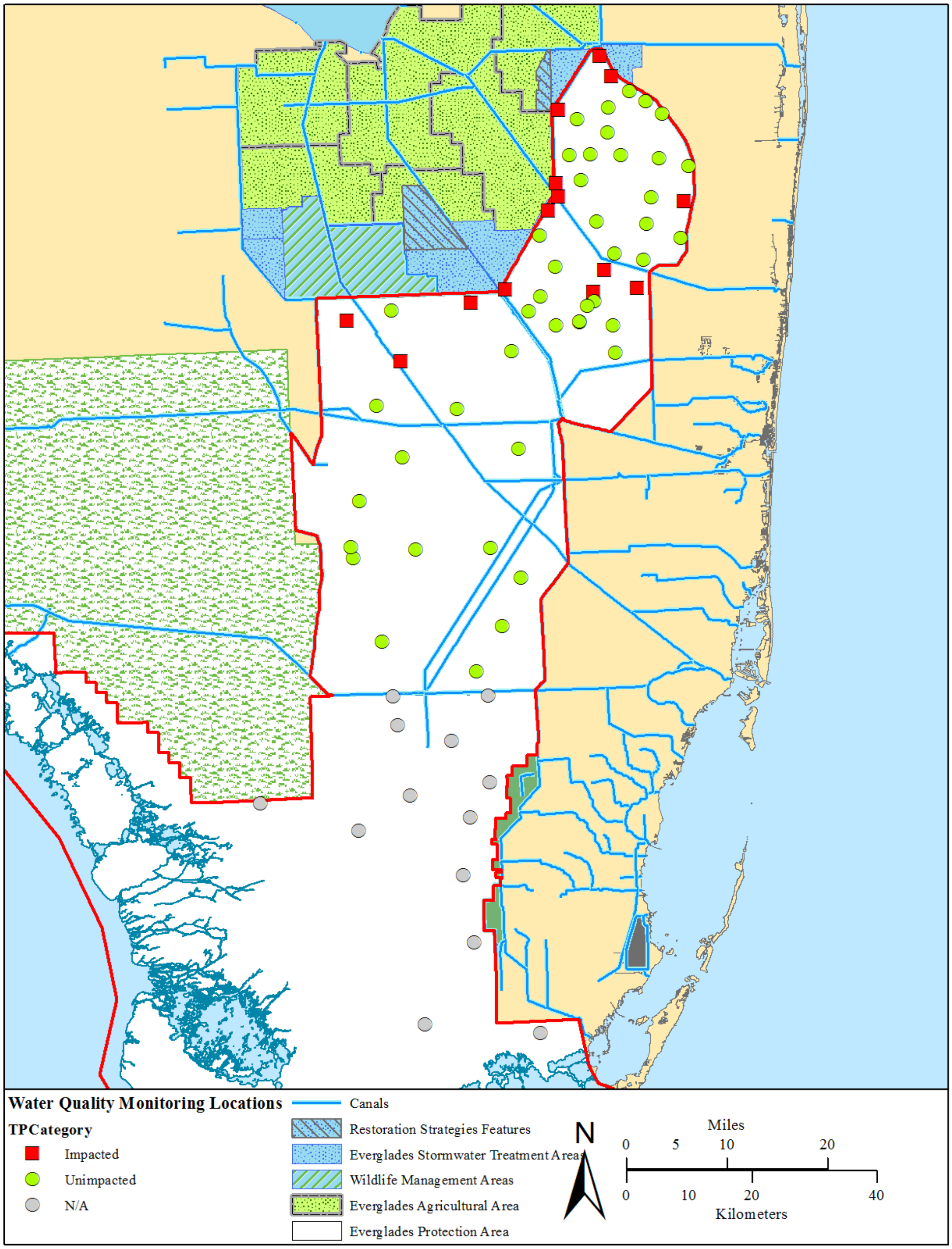

Figure 3A-5. Location of total phosphorus (TP) criterion assessment monitoring stations and their respective classifications used in Water Years 2011–2015 (WY2011–WY2015) (May 1, 2010–April 30, 2015) evaluations.

WATER YEAR 2015 WATER QUALITY RESULTS

In WY2015, an average of 265 sampling days occurred throughout the EPA. WCA-3 had the greatest number of sampling days, with 364 sampling days; 363 sampling days within ENP; 172 sampling days within the Refuge; and 160 sampling days occurred within WCA-2. Very few samples collected during WY2015 resulted in qualified data; 1.7 percent (808 qualified samples from a total of 46,352 samples collected) of the data collected was removed due to fatal qualifiers. The dominant fatal qualifier was the J qualifier (estimated value).

WATER QUALITY CRITERIA EXCURSION ANALYSIS

Summarized by region and classification, WY2015 data is included in Appendix 3A-1 of this volume. Additionally, data for the last five water years (WY2011–WY2015) summarized by region, class, and monitoring station is presented in Appendix 3A-2. Comparisons of WY2015 water quality data with applicable Florida Class III water quality criteria resulted in excursions for four water quality parameters: DO, alkalinity, pH, and specific conductance (**Table 3A-1**). Similar to previous periods, these excursions were generally isolated to specific areas of the EPA.

Water quality parameters with exceedances of applicable criteria are discussed further below, with the excursion frequencies summarized for the Baseline through the current reporting periods (WY1979–WY1993, WY1994–WY2004, WY2005–WY2014, and WY2015) to evaluate the presence of any temporal trends (**Table 3A-1**). Meanwhile, sulfate (SO_4^{2-}) summary statistics for the current water year summarized by region and classification is presented in Appendix 3A-1, and the last five water years summarized by monitoring station is provided in Appendix 3A-2. Historically, this chapter included a temporal and spatial trends analysis of SO_4^{2-} concentrations in the EPA; however, considering the theoretical link between SO_4^{2-} concentrations and mercury methylation, this information is covered in Chapter 3B of this volume.

Table 3A-1. Excursions from Florida Class III criteria in the Everglades Protection Area (EPA) for the Baseline period [Water Year (WY)1979–1993], Phase I (WY1994–WY2004), Phase II (WY2005–WY2014), and WY2015. [Note: Water year begins on May 1 and ends on April 30 of the following year.]

Area	Class	Parameter	Number of Excursions/Sample Size, Percent Excursions (Category)[1]			
			Baseline WY1979–WY1993	Phase I WY1994–WY2004	Phase II WY2005–WY2014	Current WY WY2015[4]
Refuge	Inflow	Alkalinity	5 / 1604, 0.3% (MC)	0 / 1158, 0% (NC)	0 / 1220, 0% (NC)	0 / 151, 0% (NC)
		Dissolved Oxygen[2]	551 / 1119, 49.2% (C)	950 / 2173, 43.7% (C)	662 / 2096, 31.6% (C)	39 / 204, 19.1% (C)
		pH	8 / 1100, 0.7% (MC)	4 / 2177, 0.2% (MC)	8 / 2142, 0.4% (MC)	0 / 204, 0% (NC)
		Specific Conductance	478 / 1114, 42.9% (C)	373 / 2178, 17.1% (C)	274 / 2145, 12.8% (C)	12 / 205, 5.9% (MC)
		Un-ionized Ammonia	35 / 1681, 2.1% (MC)	3 / 2309, 0.1% (MC)	7 / 1057, 0.7% (MC)	0 / 143, 0% (NC)
	Interior	Alkalinity	103 / 387, 26.6% (C)	476 / 1148, 41.5% (C)	437 / 1458, 30% (C)	58 / 125, 46.4% (C)
		Dissolved Oxygen[3]	9 / 30, 30% (C)	22 / 140, 15.7% (C)	63 / 301, 20.9% (C)	4 / 31, 12.9% (PC)
		pH	59 / 253, 23.3% (C)	131 / 1394, 9.4% (PC)	90 / 2597, 3.5% (MC)	5 / 312, 1.6% (MC)
		Specific Conductance	6 / 153, 3.9% (MC)	1 / 1365, 0.1% (MC)	0 / 2533, 0% (NC)	0 / 288, 0% (NC)
		Un-ionized Ammonia	1 / 387, 0.3% (MC)	1 / 1090, 0.1% (MC)	0 / 1326, 0% (NC)	0 / 111, 0% (NC)
	Outflow	Alkalinity	1 / 580, 0.2% (MC)	0 / 710, 0% (NC)	0 / 488, 0% (NC)	0 / 60, 0% (NC)
		Dissolved Oxygen[2]	279 / 593, 47% (C)	258 / 697, 37% (C)	84 / 666, 12.6% (C)	4 / 75, 5.3% (MC)
		pH	1 / 581, 0.2% (MC)	4 / 693, 0.6% (MC)	1 / 678, 0.1% (MC)	0 / 75, 0% (NC)
		Specific Conductance	130 / 597, 21.8% (C)	21 / 695, 3% (MC)	1 / 676, 0.1% (MC)	0 / 75, 0% (NC)
		Un-ionized Ammonia	8 / 614, 1.3% (MC)	4 / 700, 0.6% (MC)	0 / 482, 0% (NC)	0 / 114, 0% (MC)
	Rim	Dissolved Oxygen[2]	19 / 96, 19.8% (C)	199 / 454, 43.8% (C)	51 / 273, 18.7% (C)	0 / 34, 0% (NC)
		Specific Conductance	27 / 96, 28.1% (C)	57 / 459, 12.4% (C)	10 / 301, 3.3% (MC)	1 / 46, 2.2% (MC)
		Un-ionized Ammonia	0 / 96, 0% (NC)	2 / 464, 0.4% (MC)	3 / 99, 3% (MC)	N/A
WCA-2	Inflow	Dissolved Oxygen[2]	286 / 635, 45% (C)	290 / 951, 30.5% (C)	216 / 1587, 13.6% (C)	12 / 174, 6.9% (MC)
		pH	2 / 622, 0.3% (MC)	5 / 953, 0.5% (MC)	2 / 1608, 0.1% (MC)	1 / 177, 0.6% (MC)
		Specific Conductance	162 / 641, 25.3% (C)	129 / 954, 13.5% (C)	124 / 1605, 7.7% (PC)	0 / 178, 0% (NC)
		Un-ionized Ammonia	6 / 849, 0.7% (MC)	4 / 1031, 0.4% (MC)	0 / 878, 0% (NC)	2 / 242, 1.7% (C)
	Interior	Dissolved Oxygen[3]	55 / 99, 55.6% (C)	45 / 115, 39.1% (C)	41 / 179, 22.9% (C)	3 / 20, 15% (PC)
		pH	17 / 861, 2% (MC)	3 / 1836, 0.2% (MC)	2 / 1746, 0.1% (MC)	0 / 203, 0% (NC)
		Specific Conductance	85 / 754, 11.3% (PC)	193 / 1870, 10.3% (PC)	122 / 1744, 7% (PC)	10 / 199, 5% (MC)
		Un-ionized Ammonia	8 / 2011, 0.4% (MC)	4 / 1539, 0.3% (MC)	0 / 1083, 0% (NC)	0 / 144, 0% (MC)
	Outflow	Dissolved Oxygen[2]	294 / 883, 33.3% (C)	272 / 673, 40.4% (C)	233 / 846, 27.5% (C)	21 / 95, 22.1% (C)
		pH	2 / 871, 0.2% (MC)	5 / 687, 0.7% (MC)	0 / 863, 0% (NC)	0 / 95, 0% (NC)
		Specific Conductance	26 / 884, 2.9% (MC)	1 / 683, 0.1% (MC)	0 / 867, 0% (NC)	0 / 95, 0% (NC)
		Un-ionized Ammonia	3 / 893, 0.3% (MC)	2 / 697, 0.3% (MC)	0 / 630, 0% (NC)	0 / 148, 0% (MC)

Table 3A-1. Continued.

Area	Class	Parameter	Number of Excursions/Sample Size, Percent Excursions (Category)[1] Baseline WY1979–WY1993	Phase I WY1994–WY2004	Phase II WY2005–WY2014	Current WY WY2015[4]
WCA-3	Inflow	Dissolved Oxygen[2]	908 / 2113, 43% (C)	1271 / 3116, 40.8% (C)	2602 / 5925, 43.9% (C)	362 / 861, 42% (C)
		pH	17 / 2089, 0.8% (MC)	15 / 3162, 0.5% (MC)	7 / 6020, 0.1% (MC)	1 / 879, 0.1% (MC)
		Specific Conductance	58 / 2138, 2.7% (MC)	7 / 3147, 0.2% (MC)	13 / 6037, 0.2% (MC)	0 / 879, 0% (NC)
		Un-ionized Ammonia	3 / 2206, 0.1% (MC)	6 / 2835, 0.2% (MC)	5 / 1975, 0.3% (MC)	0 / 527, 0% (MC)
	Interior	Dissolved Oxygen[3]	31 / 96, 32.3% (C)	44 / 133, 33.1% (C)	20 / 135, 14.8% (C)	1 / 11, 9.1% (PC)
		pH	1 / 407, 0.2% (MC)	0 / 1935, 0% (NC)	1 / 1400, 0.1% (MC)	0 / 95, 0% (NC)
		Specific Conductance	4 / 297, 1.3% (MC)	0 / 1946, 0% (NC)	0 / 1410, 0% (NC)	0 / 95, 0% (NC)
		Un-ionized Ammonia	1 / 609, 0.2% (MC)	1 / 1486, 0.1% (MC)	0 / 1114, 0% (NC)	0 / 136, 0% (MC)
	Outflow	Dissolved Oxygen[2]	778 / 1927, 40.4% (C)	953 / 2408, 39.6% (C)	756 / 2388, 31.7% (C)	120 / 292, 41.1% (C)
		pH	24 / 1891, 1.3% (MC)	22 / 2632, 0.8% (MC)	2 / 2607, 0.1% (MC)	0 / 312, 0% (NC)
		Specific Conductance	0 / 1952, 0% (NC)	0 / 2645, 0% (NC)	0 / 2599, 0% (NC)	0 / 312, 0% (NC)
		Un-ionized Ammonia	0 / 1741, 0% (NC)	6 / 1695, 0.4% (MC)	0 / 629, 0% (NC)	N/A
ENP	Inflow	Dissolved Oxygen[2]	911 / 2289, 39.8% (C)	1250 / 3031, 41.2% (C)	917 / 2986, 30.7% (C)	125 / 322, 38.8% (C)
		pH	26 / 2252, 1.2% (MC)	33 / 3047, 1.1% (MC)	2 / 3022, 0.1% (MC)	0 / 325, 0% (NC)
		Specific Conductance	0 / 2314, 0% (NC)	1 / 3019, 0% (MC)	0 / 3004, 0% (NC)	0 / 325, 0% (NC)
		Un-ionized Ammonia	0 / 2114, 0% (NC)	23 / 2026, 1.1% (MC)	0 / 734, 0% (NC)	N/A
	Interior	Dissolved Oxygen[2]	1 / 69, 1.4% (MC)	5 / 105, 4.8% (MC)	5 / 101, 5% (MC)	3 / 9, 33.3% (C)
		pH	9 / 459, 2% (MC)	27 / 1023, 2.6% (MC)	0 / 839, 0% (NC)	0 / 84, 0% (NC)
		Un-ionized Ammonia	14 / 568, 2.5% (MC)	4 / 1007, 0.4% (MC)	1 / 628, 0.2% (MC)	0 / 57, 0% (NC)

[1] Excursion categories of concern, potential concern, minimal concern and no concern are denoted by "C," "PC," "MC," and "NC", respectively.

[2] DO for inflow, outflow, and Rim Canal sampling locations were assessed using the Florida Class III freshwater water quality standard identified in Section, 62-302.533, F.A.C.

[3] Dissolved oxygen (DO) site-specific alternative criterion was used to assess water quality excursions.

[4] Due to low sample size, some of these estimates should be used with caution.

Dissolved Oxygen

Marsh DO conditions within the EPA were assessed utilizing the Everglades DO site-specific alternative criterion (SSAC) for all periods, even though the SSAC was developed and implemented during 2004. To be consistent among time periods, the DO SSAC was applied across all periods. Because a single-value criterion does not adequately account for the wide-ranging natural daily fluctuations observed in the Everglades marshes, the SSAC uses an algorithm that includes sample collection time and water temperature to model the observed natural sinusoidal diel cycle and seasonal variability (Weaver, 2004). The DO SSAC was originally developed to assess DO conditions within the EPA (i.e., marsh interior stations); therefore, for this analysis DO SSAC was applied to interior monitoring locations. Compliance with the DO water quality standard for inflow, outflow, and Rim Canal monitoring locations was assessed using the Class III standard (discussed below); however, for informational purposes only the DO SSAC was also applied to inflow, outflow, and Rim Canal monitoring locations and presented in Appendix 3A-3 of this volume. The SSAC is assessed based on a comparison between the annual average measured DO concentration and average of the corresponding DO limits. DO excursion results for WY2015 for individual stations are provided in Appendix 3A-3 of this volume.

During WY2015, eleven interior stations (LOXA104.5, LOXA130, Z1, Z2, FS1, WCA2F1, WCA2F2, CA318, NE1, P33, and P36) exceeded the DO SSAC. It should be noted that only one sample was collected LOXA130. Interior marsh stations that failed to achieve the SSAC during WY2015 either reside within phosphorus-impacted areas or are heavily influenced by canal flow. Phosphorus impacted areas of the marsh have long-term surface water TP concentrations greater than 10 micrograms per liter (µg/L) and sediment TP concentrations in excess of 500 milligrams per kilogram (mg/kg). The DO SSAC was originally developed to assess DO concentrations within the marsh and never intended to be applied to Rim Canal, inflow, and outflow monitoring locations. However, for comparison purposes only, the DO SSAC was applied to Rim Canal, inflow, and outflow monitoring locations (Appendix 3A-3, Table 1).

DO for inflow, outflow, and Rim Canal monitoring stations were assessed using the Class III freshwater water quality standard (authorized August 1, 2013), which states that "no more than 10 percent of the daily average percent DO saturation (% DO) values shall be below 38 percent in the Everglades Bioregion for daily data (Section 62-302.533, F.A.C.) or for instantaneous data (discrete measurements) the % DO values shall not exceed the limit based on the calculated time-day specific translation" (FDEP, 2013). For WY2015, several inflow, outflow, and rim stations (49 out of 69) exceeded the DO water quality standard (WQS). A detailed list of stations, summary statistics, and WQS pass/fail determination is presented in Appendix 3A-3, Table 2. For comparison purposes only, DO Class III (freshwater) WQS was applied to interior monitoring locations.

Inflow regions for the Refuge, WCA-3, and ENP were classified as a concern for all periods. Inflows into WCA-2 have progressed from an area of concern during the Baseline and Phase I periods to potential concern during Phase II and minimal concern during the current WY. The Rim Canal region of the Refuge also saw improvement and progressed from an area of concern during the Baseline, Phase I, and Phase II periods to an area of no concern during the current WY. Outflow regions for WCA-2, WCA-3, and ENP were classified as a concern for all periods, while outflow from the Refuge has improved from a concern during the Baseline period to a minimal concern during the current WY. Excursion frequencies throughout the different periods (Baseline, Phase I, and Phase II) have in large part either been reduced or remained the same, with the exception of WCA-3 and ENP (**Table 3A-1**).

Unlike most other parameters, DO is not a direct pollutant. Instead, it is a secondary response parameter that reflects changes in other pollutants or physical or hydrologic changes in the system. The FDEP recognizes that DO impairments in phosphorus-impacted areas are related to biological changes caused by phosphorus enrichment (Weaver, 2004). Phosphorus concentrations in excess of the numeric criterion produce a variety of system changes in the Everglades that ultimately depress the DO regime in the water column (Payne and Xue, 2012). The District is actively implementing a comprehensive restoration program to lower TP concentrations within the phosphorus-impacted portions of the EPA. Over time, DO concentrations at the nutrient impacted sites are expected to continue to improve as phosphorus concentrations in surface water and sediment are reduced and biological communities recover.

Compliance with the DO SSAC is based on the annual average of the instantaneous (discrete) DO measurements for each site; sufficient annual average DO data is not available for a single year to confidently apply the binomial hypothesis test to the regional assessment units. Therefore, excursion categories for DO were assigned based on a five-year period of record (POR)(WY2011–WY2015). Using the DO SSAC, interior portions of the Refuge, WCA-2 and WCA-3 were categorized as a concern, and minimal concern for interior portions of ENP for the WY2011–WY2015 period. A summary of water quality monitoring data for the five-year POR period is presented in Appendix 3A-2, and analysis of the WY2015 data is provided in Appendix 3A-3 for each individual monitoring location. It should be noted that no definitive conclusions regarding differences in DO excursion rates between individual water years and previous periods can be made given the large disparity in sample sizes among periods.

Alkalinity and pH

Alkalinity is the measure of water's acid neutralization capacity and provides a measure of the water's buffering capacity. In most surface water bodies, the buffering capacity is primarily the result of the equilibrium between carbon dioxide (CO_2), bicarbonate (HCO_3^-), and carbonate ions (CO_3^{2-}). The dissociation of calcium carbonate, magnesium carbonate, or other carbonate-containing compounds entering the surface water through weathering of carbonate-containing rocks and minerals (e.g., limestone and calcite) contributes to the water's buffering capacity. Therefore, in certain areas that are influenced by canal inflows primarily composed of mineral-rich agricultural runoff and groundwater (such as ENP, WCA-2, and WCA-3), alkalinity concentrations are relatively high (Payne and Xue, 2012). Conversely, areas such as the Refuge interior, which receive their hydrologic load primarily through rainfall, have very low alkalinities. Alkalinity [i.e., calcium carbonate ($CaCO_3$)] protects against dramatic pH changes, which can be lethal to sensitive organisms. The current Class III water quality criterion specifies that alkalinity shall not be lower than 20 milligrams per liter (mg/L) of alkalinity as calcium carbonate.

Excursions from the alkalinity water quality criterion have historically occurred in the Refuge interior (Payne and Xue, 2012). During WY2015, alkalinity was designated as a concern for the Refuge interior because of an excursion rate of 46.4 percent (**Table 3A-1**). However, as discussed above and in previous SFERs, the Refuge interior is hydrologically dominated by rainfall, which is naturally low in alkalinity. As such, the FDEP considers the low alkalinity values to be representative of the range of natural conditions within the Refuge; therefore, these are not considered violations of state water quality standards. The excursion rate for alkalinity in the Refuge interior during WY2015 was higher than the rates of reported for the Baseline, Phase I, and Phase II periods (26.6, 41.5, and 29.5 percent, respectively). In WY2015, alkalinity excursions occurred at numerous stations including the following sites (number of exceedances for each site in parentheses): LOX7 and LOX8 (10); LOX11and LOX13 (8); LOX9 (7); LOX5 and LOX3 (5); LOX10 (4); and LOX14 (1).

pH is defined as the negative $\log_{(base10)}$ of the hydrogen (H^+) ion activity. Most organisms, especially aquatic life, function best in a pH ranging from 6.0 to 9.0, although individual species have specific ideal ranges. In WY2015, pH was considered a minimal concern for the Refuge Interior, WCA-2 and WCA-3 inflows. For Refuge interior sites, pH levels occasionally fell slightly below the 6.0 minimum criteria at three of the monitoring locations. The pH excursions were recorded for the following sites (number of excursions for each site provided in parentheses): LOX8 (3), LOX11 (1), LOX5 (1), and LOX7 (1). As pH excursions within the Refuge interior generally occur at sites distanced from the influence of inflows and have been linked to natural low background alkalinity conditions, the FDEP does not consider the pH excursions in this area to be a violation of state water quality standards.

Specific Conductance

Specific conductance (conductivity) is a measure of water's ability to conduct an electrical current and is an indirect measure of the total concentration of ionized substances (e.g., Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, HCO_3^{-}, and SO_4^{2-}) in the water. Conductivity varies with the quantity and type of ions present in solution. The current state water quality criteria for Class III freshwater allows for a 50 percent increase above background conditions in specific conductance or 1,275 microsiemens per centimeter (µS/cm), whichever is greater. This limit is meant to preserve natural background conditions and to protect aquatic organisms from stressful ion concentrations. Given that background conductivities are low within the EPA, excursions were calculated using the 1,275 µS/cm criterion (Payne and Xue, 2012).

For WY2015, specific conductance was categorized as a potential concern for Refuge inflows and minimal concern for Refuge rim, WCA-2 inflow, and interior regions and minimal concern for the interior of ENP (**Table 3A-1**). Specific conductance excursion category for the Refuge has improved since the last WY, moving from a category of concern to potential concern; this improvement could be due to improved water management as excursion frequencies have decreased at the structures which typically exceed this WQS. Exceedances in the Refuge occurred at the G-338 (2 excursions) and S-362 (10 excursions) inflow structures, which overall had 12 specific conductance measurements above 1,275 µS/cm as compared to WY2014, with a total of 18 exceedances recorded between these two stations. The Refuge rim monitoring location LOXA135 observed one sample above the water quality standard during WY2015. In WCA-2, interior stations WCA2F3 (3); CA27 (2); and CA29, U3, WCA2F1, WCA2F4, and 2AN4 (1) exhibited exceedances in WY2015. Elevated conductivity levels at water control structures and stations near canal inflows may be explained by groundwater intrusion into canal surface waters (Payne and Xue, 2012; Krest and Harvey, 2003). This groundwater intrusion can occur due to seepage into canals via pump station operation (which can pull additional groundwater into surface water) and as a result of agricultural dewatering practices. However, improvements in water management and agricultural BMPs have reduced the occurrences of these high conductivity waters entering the EPA.

Specific conductance excursion frequency in the Refuge inflows decreased from 42.9 to 17.1 percent during the Baseline and Phase I periods, respectively; a continued decrease to 12.8 percent during Phase II and 5.9 percent in WY2015 was observed. Excursion rates in WCA-2 inflows declined from 24.9 and 13.5 percent during the Baseline and Phase I periods, respectively, to 7.7 percent in Phase II and decreased to no observed excursion in WY2015. Excursion frequency in WCA-3 inflows steadily decreased throughout the Baseline, Phase I, and Phase II periods (2.7, 0.2, and 0.2 percent, respectively) and further decreased to no excursions during WY2015.

Overall, a steady long-term decrease in specific conductance within the Refuge, WCA-2, WCA-3, and ENP inflows has occurred since WY1979 (**Figure 3A-6**). Median annual specific conductance levels in the Refuge inflows have decreased approximately 424 µS/cm over the POR with a rate of approximately 9.5 µS/cm per year (across the entire POR). Similarly, across the sample period specific conductance has decreased 356 µS/cm and 207 µS/cm in WCA-2 inflows and WCA-3 inflow, respectively. The rate of decrease is slightly lower than the Refuge for WCA-2 and WCA-3 with a 6 µS/cm per year and 4 µS/cm per year for each region, respectively. For

WY2015, ENP experienced a decrease of 152 µS/cm from WY1979 to WY2015 with a rate of 1 µS/cm per year.

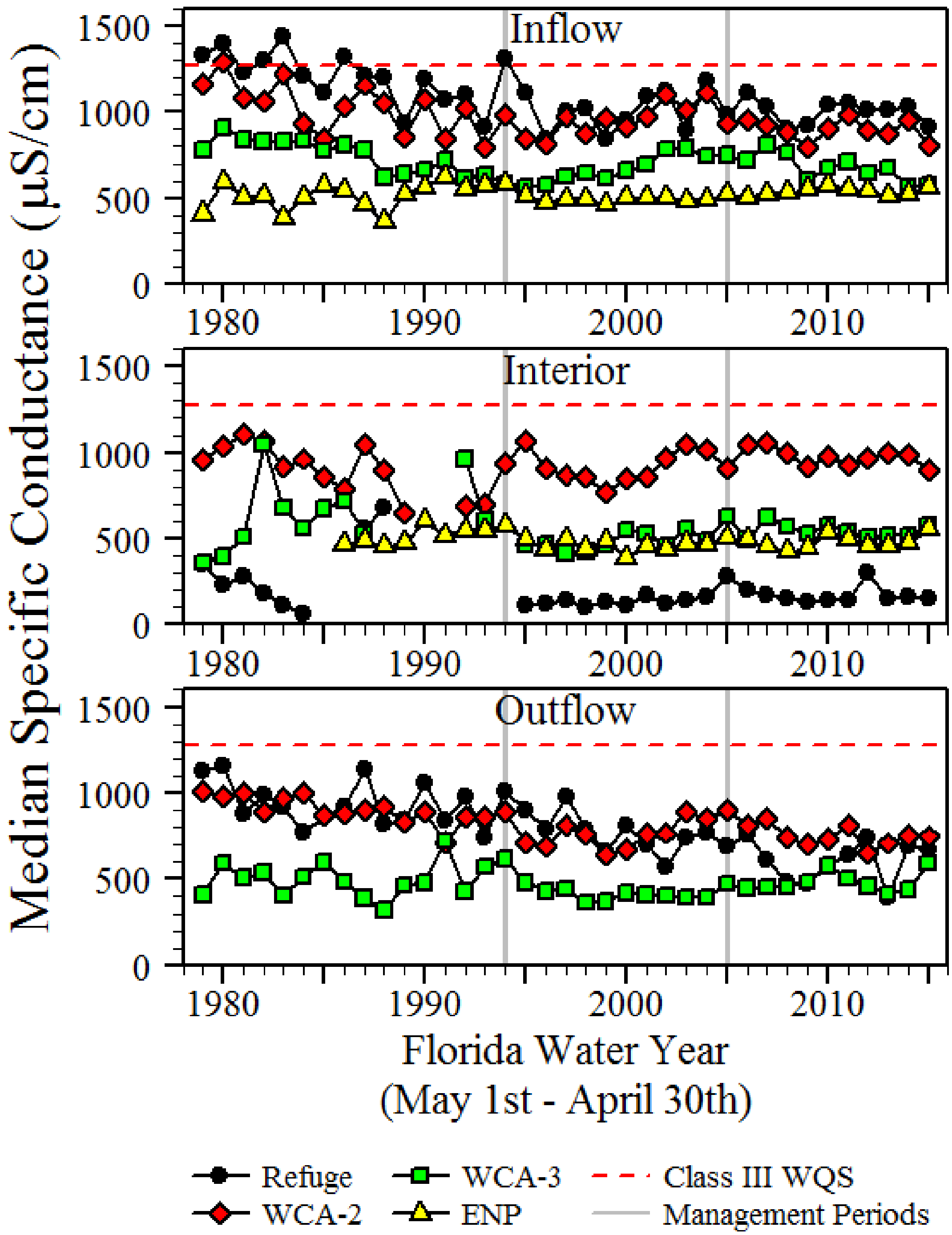

Figure 3A-6. Annual median specific conductance levels in microsiemens per centimeter (µS/cm) in the Everglades Protection Area (EPA) (A) inflows, (B) interior, and (C) outflows for WY1979–WY2015.

Un-ionized Ammonia

Ammonia is the principal excretory product in aquatic animals and its mechanisms of toxicity are relatively well understood (Armstrong et al., 1978; Thurston and Russo, 1981; Neil et al., 2005). The toxic effects of ammonia to aquatic species are generally considered to be caused by the un-ionized fraction (NH_3), rather than the ionic components (NH_4^+), which exist in equilibrium. This equilibrium is highly dependent on pH, temperature, pressure, and salinity (Hampson, 1977). The current Class III freshwater water quality standard states that the un-ionized ammonia concentration shall be less than or equal to 0.02 mg/L as ammonia (NH_3), this criterion has been adopted by the state to protection aquatic life from the toxic effects of un-ionized ammonia and is not a nutrient-related criterion.

During WY2015, there was only one exceedances of the ammonia WQS observed at one WCA-2 inflow location (G-335; 0.042 mg/L). For WY2015, 29 percent of the calculated un-ionized ammonia concentrations were below the FDEP-approved target MDL of 0.4 µg/L [Subsection 62-4.246(4), F.A.C.)] for all areas and regions during WY2015. Historically, un-ionized ammonia was considered a minimal concern for most areas of the EPA during the Baseline, Phase I, and Phase II periods, with all areas showing improving with respect to percent exceedances occasionally water quality standard exceedances are observed (**Table 3A-1**).

Pesticides

The District has been actively monitoring pesticides since 1976 (Pfeuffer, 1985) and, since 1984, has established a routine pesticide monitoring program (Pfeuffer and Rand, 2004). The pesticide monitoring network includes sites designated in the permits for Lake Okeechobee operations and non-Everglades Construction Projects (non-ECP). Results of monitoring conducted as part of these permits are provided in Volume III of the annual SFER. The current EPA monitoring program consists of 19 sites and is conducted on a biannual basis (**Figure 3A-7**). A subset of sampling stations from the entire pesticide monitoring network was used for analysis.

Surface water concentrations of pesticides are regulated under criteria presented in Chapter 62-302, F.A.C. Chemical-specific numeric criteria for several pesticides and herbicides (e.g., DDT, and malathion) are listed in Section 62-302.530, F.A.C. Compounds not specifically listed, including many contemporary pesticides (e.g., ametryn, atrazine, and diazinon), are evaluated based on acute and chronic toxicity. A set of toxicity-based guidelines for non-listed pesticides was presented by Weaver (2001). These guidelines were developed based on the requirement in Subsection 62-302.530(62), F.A.C., which calls for Florida's surface waters to be free from "substances in concentrations, which injure, are chronically toxic to, or produce adverse physiological or behavioral response in humans, plants, or animals."

Surface water pesticide data is typically collected biannually for most monitoring locations within the network. Compliance with pesticide water quality standard is assessed annually, therefore only WY2014 data is presented. During WY2015, 11 pesticide or pesticide breakdown products were detected at concentrations above their respective MDLs within the EPA. These compounds include 2,4,5-T (Trichlorophenoxyacetic acid), 2,4-D, ametryn, atrazine, atrazine desethyl, diuron, imidacloprid, metolachlor, metribuzin, norflurazon, and silvex. None of the compounds detected during WY2015 exceeded the toxicity guideline concentrations; therefore, annual arithmetic mean, minimum, and maximum concentrations are presented (**Table 3A-2**). This is the third consecutive year in which pesticide or pesticide breakdown products were detected at concentrations above their MDLs but did not exceed state water quality criteria.

Table 3A-2. Surface water detected pesticide concentrations in micrograms per liter (µg/L) for WY2015[1].

Area	Parameter	Arithmetic Mean Concentration (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Total Samples
Refuge	2,4-D	0.078	0.010	0.150	4
	Ametryn	0.050	0.031	0.058	4
	Atrazine	0.183	0.100	0.300	4
	Atrazine Desethyl	0.023	0.016	0.029	4
	Metolachlor	0.150	0.150	0.150	4
	Metribuzin	0.120	0.120	0.120	4
WCA2	2,4-D	0.003	0.002	0.003	4
	Ametryn	0.044	0.026	0.053	3
	Atrazine	0.276	0.074	0.440	4
	Atrazine Desethyl	0.024	0.013	0.040	4
	Metribuzin	0.054	0.034	0.073	3
WCA3	2,4,5-T	0.003	0.003	0.003	24
	2,4-D	0.029	0.004	0.190	24
	Ametryn	0.026	0.012	0.033	24
	Atrazine	0.086	0.015	0.190	23
	Atrazine Desethyl	0.020	0.020	0.020	24
	Diuron	0.004	0.003	0.004	21
	Imidacloprid	0.005	0.004	0.007	21
	Norflurazon	0.037	0.034	0.039	24
	Silvex	0.006	0.006	0.006	24
ENP	2,4-D	0.023	0.008	0.035	12
	Atrazine	0.060	0.023	0.110	12
	Diuron	0.005	0.005	0.005	9
	Imidacloprid	0.009	0.003	0.014	9
	Metribuzin	0.021	0.021	0.021	12

[1] No detectable pesticide or breakdown by-product was detected above pesticide surface water criteria; therefore, reporting of excursion criteria is not applicable.

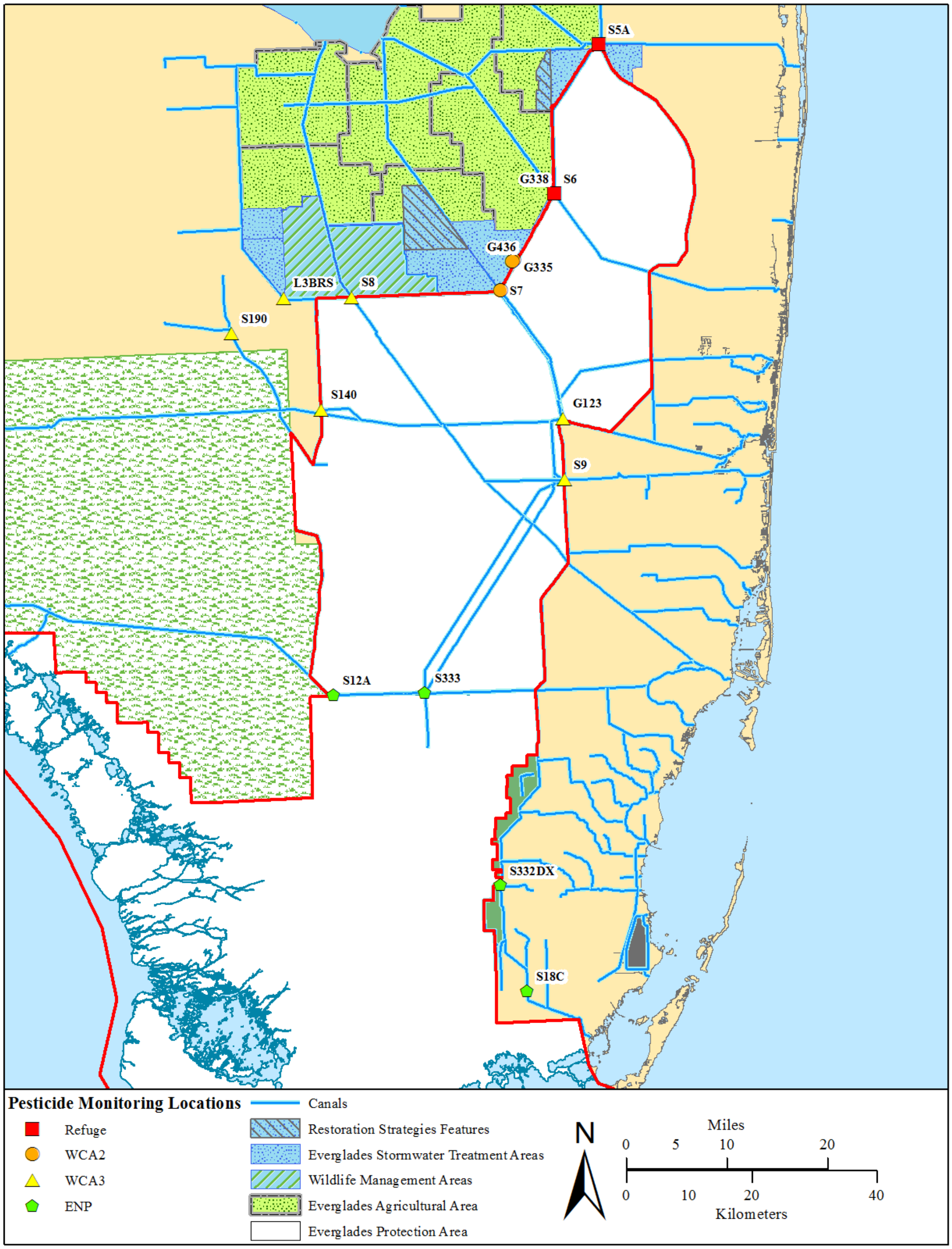

Figure 3A-7. EPA inflow pesticide and other toxicant monitoring locations. Monitoring locations for each region of the EPA are identified by a different symbol and color.

PHOSPHORUS AND NITROGEN

Phosphorus and nitrogen are essential to the existence and growth of aquatic organisms in surface waters. The EPA and, to a larger extent, the Everglades ecosystem is a phosphorus-limited system (Noe et al., 2001). The native flora and fauna in the Everglades are adapted to nutrient-poor conditions; therefore, relatively small additions of nutrients, especially phosphorus, have dramatic effects on the ecosystem.

Until the adoption of the numeric TP criteria, both phosphorus and nitrogen concentrations in EPA surface waters were only regulated by Class III narrative criterion. The narrative criterion specifies that nutrient concentrations in a water body cannot be altered to cause an imbalance in the natural populations of aquatic flora or fauna. Because of the importance of phosphorus in controlling natural biological communities, the FDEP has numerically interpreted the narrative criterion, as directed by the EFA, to establish a long-term geometric mean of 10 µg/L TP for the EPA. Currently, nitrogen does not have a numeric criterion and is still regulated by only the narrative criteria.

In addition to presenting analyses of individual TP and TN concentrations, this chapter provides an evaluation of spatial and temporal trends in nutrient concentration and loads within the EPA as measured during WY2015 and compares the results with previous monitoring periods to provide an overview of the changes in nutrient levels within the EPA.

Total Phosphorus Concentrations

One of the primary objectives of this chapter is to document temporal changes in TP levels across the EPA using long-term geometric means to summarize and compare TP concentrations in accordance with the EFA and TP criterion rule requirements. The EFA and TP criterion were designed to provide long-term, ecologically protective conditions and require the use of geometric means due to the log-normal distribution of natural TP concentrations in the environment. The geometric mean employed by the criterion and the methodology used in this chapter to assess the nutrient concentrations account for short-term variability in water quality data, while providing more reliable, long-term values for evaluation and comparison of nutrient status.

Temporal changes in annual geometric mean TP concentrations during the POR from WY1979–WY2015 at both inflow and interior sites of the Refuge, WCA-2, WCA-3, and Park are shown in **Figure 3A-8**. Additionally, average geometric mean TP concentrations for the Baseline, Phase I, Phase II, and WY2015 periods for comparison are shown in **Figure 3A-9**. A descriptive statistics summary of TP concentrations measured within each portion of the EPA during the Baseline, Phase I, Phase II, and WY2015 periods is provided in **Table 3A-3**.

During the Baseline period, annual geometric mean TP concentrations at inflow and interior marsh sites across the EPA reached peak historic concentrations and were highly variable, as shown in **Figure 3A-8**. As the agricultural BMP and STA programs were initiated and became operational during the Phase I period, annual mean TP concentrations were reduced markedly and became less variable compared to levels observed during the Baseline period. Additionally, due to extreme climatic events and low water elevations during the mid-1980s, TP concentrations remained relatively high, while the 1990s experienced higher water levels and lower TP concentrations (McCormick et al., 1998; also, see Appendix 2-3 of this volume). Effectiveness of continued optimization and enhancement of BMPs and STAs on phosphorus concentrations and loads during Phase II has been difficult to assess due to climatic extremes that have occurred during this period.

TP concentrations during the early and mid-portions of the Phase II period were dramatically influenced by climatic extremes, including active hurricane seasons with intense rainfall and periods of extended drought with little or no rainfall and subsequent marsh dryout. In general, the greatest effect from climatic extremes was experienced during WY2005 and WY2006 when tropical activity (e.g., Hurricane Wilma) resulted in elevated inflow concentrations, in concert with storm damage to STA vegetative communities, which resulted in decreased STA nutrient removal for many months. Decreased rainfall in WY2005 led to prolonged periods of marsh dryout, which resulted in increased oxidation of the organic sediment and the subsequent release of phosphorus into the water column. This release, in turn, resulted in elevated TP concentrations at marsh sites across the EPA. In recent years, several storm events have influenced rainfall and inflow volumes to the EPA but not to the extent of the 2004–2005 hurricane seasons (WY2005 and WY2006).

During WY2006, much of the EPA experienced varying levels of recovery from the climatic events of WY2005. However, TP concentrations in portions of the EPA were again influenced by extended periods of limited rainfall and the subsequent marsh dryout during WY2007, WY2008, and portions of WY2009 (**Figure 3A-8**). As the Phase II BMP and STA implementation period is expanded, results will most likely be influenced less by single atypical years (e.g., WY2005), and the long-term effects of continuing restoration efforts will become more clear.

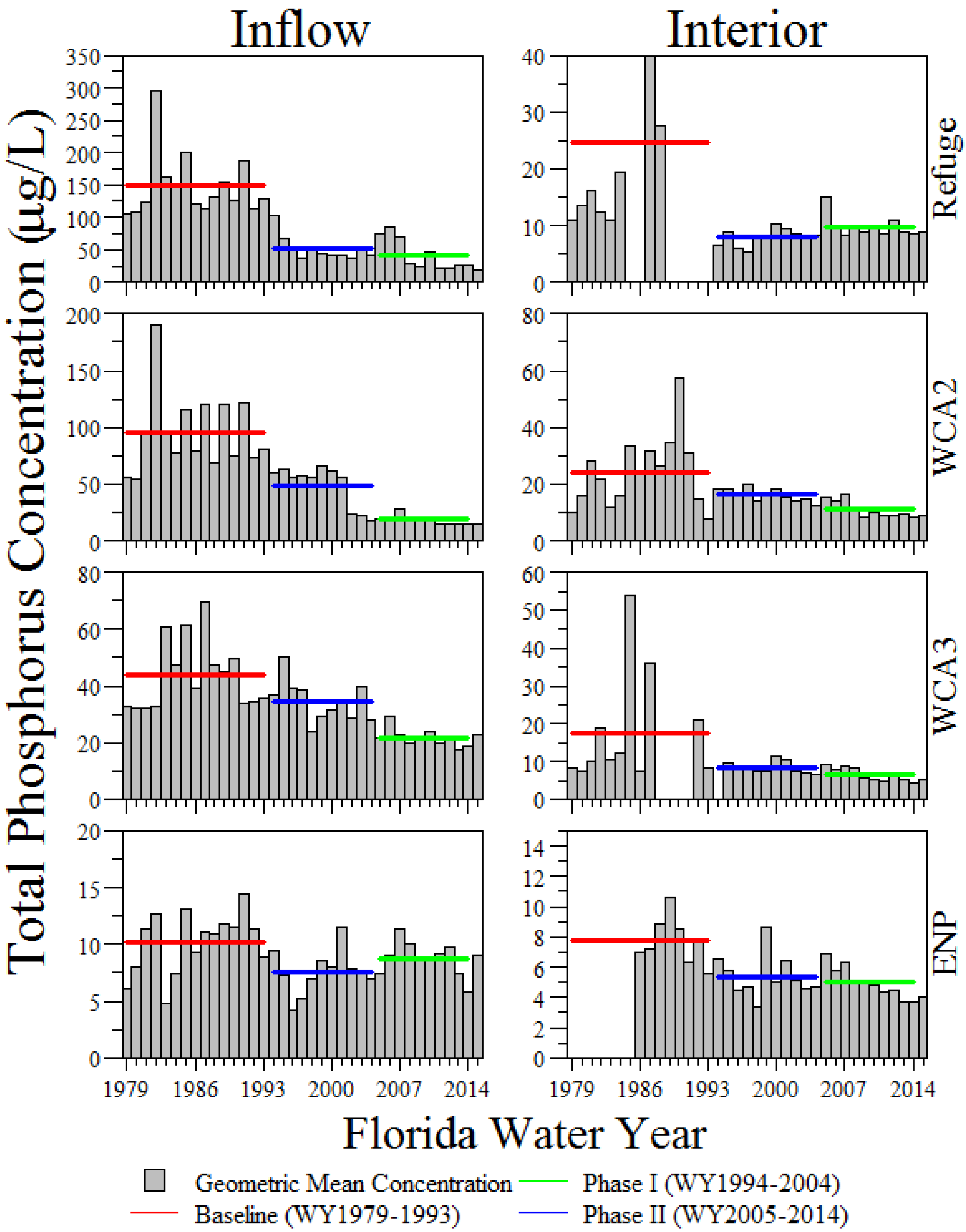

Figure 3A-8. Annual geometric mean TP concentrations in micrograms per liter (µg/L) for inflow (left panel) and interior (right panel) areas of the Refuge, WCA-2, WCA-3, ENP from WY1979–WY2015. Bars indicate geometric mean when flow, dash-line indicates geometric mean irrespective of flow. The horizontal lines indicate the mean annual geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2014) periods. [Note: Areas with no bars indicate data gaps. Additionally, for WY1987 the Refuge interior annual geometric mean TP concentrations reached 85 µg/L (outside the current scale).]

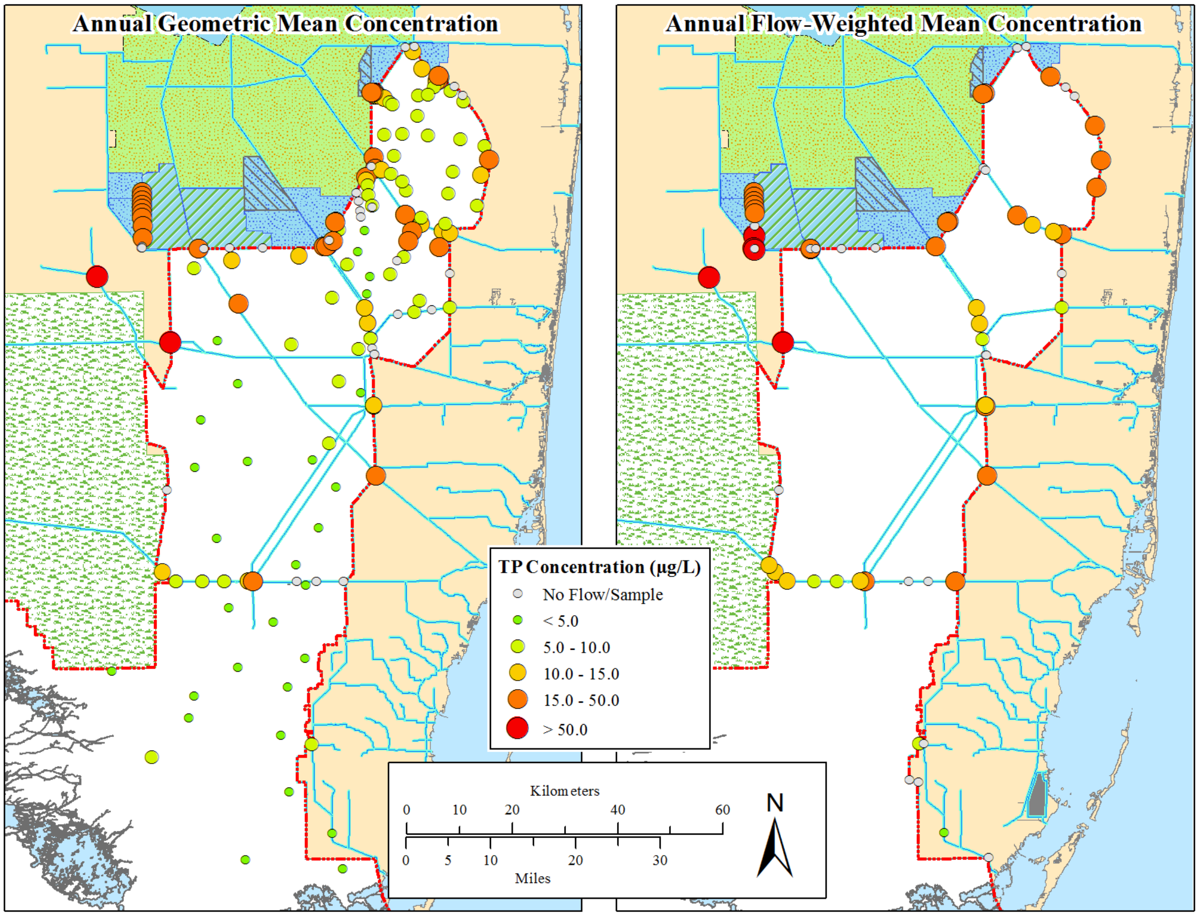

Figure 3A-9. Annual geometric mean TP concentrations (µg/L) for all classifications (left panel) and annual flow-weighted mean total phosphorus concentrations at water control structures (right panel) for WY2015 at stations across the EPA.

Table 3A-3. Summary statistics of TP concentrations (µg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2014), and WY2015.

Region	Class[1]	WY Period	Sample Size	Geometric Mean	Geometric Standard Deviation	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	413	134.3	6.8	139	14	872
		1994-2004	1569	46.7	6.1	44	6	799
		2005-2014	1016	38.2	5.7	33	3	870
		2015	138	19	4.3	19	5	45.5
	Interior	1979-1993	381	13.7	5.3	12	<2	494
		1994-2004	1493	7.9	3.7	8	2	80
		2005-2014	3119	9.8	4.2	8	2	574
		2015	369	9	3.7	8	4	72
	Outflow	1979-1993	323	63.8	6.4	68	8	674
		1994-2004	275	41.6	5.7	39	6	392
		2005-2014	177	24.4	5.3	20	8	245
		2015	26	14.3	4.1	13.5	9	47
	Rim	1979-1993	96	84.5	6.3	89	22	473
		1994-2004	479	67.5	6	68	2	263
		2005-2014	306	47.9	6.1	41	10	817
		2015	48	19.3	4.3	18	13	38
WCA-2	Inflow	1979-1993	451	80.2	6.4	82	8	1030
		1994-2004	719	37.9	5.8	43	8	392
		2005-2014	940	17.9	4.5	16.5	7	245
		2015	156	15.2	4.1	15	7.5	32
	Interior	1979-1993	2001	20.2	6.6	16	<2	3189
		1994-2004	1810	16.3	5.8	12	<2	5652
		2005-2014	2373	10.3	4.4	9	<2	278
		2015	273	8.8	4.1	8	2	107
	Outflow	1979-1993	577	24.6	5.8	25	<2	403
		1994-2004	435	14.7	4.8	14	2	199
		2005-2014	512	11.1	4	10	3	72
		2015	55	9.1	3.8	9	4	33
WCA-3	Inflow	1979-1993	1263	43.1	6.5	47	<2	933
		1994-2004	1994	32.2	5.8	32	2	679
		2005-2014	2349	21.3	5.1	19	3	368
		2015	351	23.7	5.3	25	4	1296
	Interior	1979-1993	592	10.4	5.5	10	<2	438
		1994-2004	1909	8.2	4.2	8	<2	310
		2005-2014	2025	6.4	3.7	6	<2	180
		2015	179	5.3	3.3	5	2	74
	Outflow	1979-1993	1316	11.1	4.5	11	<2	246
		1994-2004	1398	8.1	3.9	8	2	140
		2005-2014	3153	10.4	4	10	3	390
		2015	332	13.2	4.5	11	6	192
ENP	Inflow	1979-1993	1626	10.1	4.4	10	<2	246
		1994-2004	1884	7.2	3.8	7	2	297
		2005-2014	4827	8.7	3.8	8	2	1020
		2015	589	9	4.2	8	2	192
	Interior	1979-1993	505	7.7	4.7	7	2	521
		1994-2004	926	5.2	3.8	5	<2	117
		2005-2014	1097	4.7	3.4	4	<2	291
		2015	125	4.1	3	4	2	21

[1] Inflow and Outflow values only utilizes data when structures are flowing.

As documented in previous years, annual geometric mean TP concentrations measured during WY2015 exhibited a general north-south-concentration gradient with Refuge inflow concentrations achieving 19.0 µg/L TP (when flowing) and ENP inflows achieving 9.0 µg/L TP (when flowing). However, WCA-3 inflows were highest amongst all inflow regions of the EPA achieving a geometric mean TP concentration of 22.5 µg/L (when flowing). The north-to-south gradient results from phosphorus-rich canal discharges, which are composed primarily of agricultural runoff originating in the EAA that enter the northern portions of the EPA. Settling, sorption (both adsorption and absorption), biological assimilation, and other biogeochemical processes result in decreasing concentrations as the water flows southward through the marsh (**Figure 3A-9**). A detailed, site-specific summary of the TP concentrations for WY2015 is provided in Appendix 3A-4 of this volume.

Annual geometric mean inflow TP concentrations during WY2015 were 19.0 µg/L for the Refuge, 15.2 µg/L for WCA-2, 22.5 µg/L for WCA-3, and 9.0 µg/L for ENP (**Table 3A-3**). Geometric mean TP concentrations have continued to decrease, with annual geometric mean concentrations during WY2015 being lower than values reported for WY2014 for Refuge and WCA-2 while WCA-3 and ENP inflow geometric means were greater (**Figure 3A-8**). Inflow TP concentrations in the Refuge and WCA-2 generally continued to decrease following the elevated concentrations observed in WY2005.

During WY2015, the Refuge inflow TP concentration was lower than the previous water year (WY2014; 26.6 µg/L), with a geometric mean of 19.0 µg/L. Furthermore, the geometric mean TP concentration during WY2015 was reduced compared to concentrations of 134.3 µg/L, 47.0 µg/L, and 38.2 µg/L for the Baseline, Phase I, and Phase II periods, respectively (**Table 3A-3**). Likewise, geometric mean TP concentrations in WCA-2 inflows have progressively decreased from 81.2 µg/L in the Baseline period to 38.0 µg/L in the Phase I, 18.0 µg/L in the Phase II period, and 15.2 µg/L in WY2015. WCA-3 inflow geometric mean TP concentrations have also exhibited a continual decrease, dropping from 43.0 µg/L in the Baseline period to 21.3 µg/L during Phase II however WY2015 experienced a slight increase relative to Phase II with a concentration of 22.5 µg/L. The lower TP concentrations in Refuge, WCA-2, and WCA-3 inflows over the four monitoring periods are likely the result of multiple variables, including improved treatment by STAs, tighter BMP control, lower stormwater volumes resulting from periods of limited rainfall, and a general recovery from the damage resulting from the WY2005 hurricanes. Meanwhile, ENP inflow TP concentrations have remained relatively low, with a geometric mean concentration of 9.0 µg/L during WY2015, which is slightly higher than 10.2 µg/L, 7.2 µg/L, and 8.7 µg/L geometric mean concentrations for the Baseline, Phase I, and Phase II periods, respectively (**Table 3A-3**). Trends in inflow annual geometric mean TP concentrations for the Refuge, WCA-2, and WCA-3 significantly declined throughout the POR (i.e., WY1979–WY2015) with a magnitude of change ranging between -3.98 to -0.81 µg/L per WY (**Table 3A-4**). However, there was no significant trend in inflow annual geometric mean TP concentrations for ENP (**Table 3A-4**).

Table 3A-4. Kendall's τ annual geometric mean TP concentration trend analysis results for each region's inflow and interior classification within the EPA for the entire POR (WY1979–WY2015). Statistically significant ρ-values are italicized.

		POR (WY1979–WY2015)		
Area	**Class**	**Kendall's τ**	**ρ-value**	**Sen's Slope Estimate[1]**
Refuge	Inflow	-0.64	*<0.01*	-3.98
	Interior	-0.19	0.15	-0.08
WCA-2	Inflow	-0.69	*<0.01*	-2.72
	Interior	-0.50	*<0.01*	-0.48
WCA-3	Inflow	-0.55	*<0.01*	-0.81
	Interior	-0.52	*<0.01*	-0.17
ENP	Inflow	-0.13	0.27	-0.05
	Interior	-0.54	*<0.01*	-0.13

[1] Expressed as µg/L per WY

Interior marsh annual geometric mean TP concentrations observed across the EPA during WY2015 were lower relative to inflow structures. During WY2015, interior geometric mean TP concentrations ranged from 9.0 µg/L in the Refuge, 8.7 µg/L in WCA-2, 5.3 µg/L in WCA-3, and 4.1 µg/L in the Park. As reported for previous years, the geometric mean TP concentrations for most individual Park interior sites were below 10 µg/L, with the lowest annual geometric mean concentration at a particular site being recorded at P37 with a concentration of 2.7 µg/L (**Figure 3A-9**). Marsh conditions are influenced significantly by marsh stage elevation; during extremely dry years, marsh concentrations become significantly elevated, as evidenced in high TP concentrations within the Refuge during the late 1980s (**Figure 3A-8**; WY1987: 85.4 µg/L and WY1988: 27.5 µg/L).

The most dramatic decreases in interior marsh TP concentrations in recent years have been observed for WCA-2 and WCA-3. For the Baseline and Phase I periods, the geometric mean TP concentrations in WCA-2 have remained relatively constant, with geometric mean concentrations of 20.2 µg/L and 16.3 µg/L, respectively (**Table 3A-4**). Further decreases during Phase II and WY2015 have been observed, with geometric mean concentrations decreasing to 10.2 µg/L and 8.7 µg/L, respectively. Likewise, interior geometric mean TP concentrations within WCA-3 has steadily decreased from 10.4 µg/L during the Baseline period to 8.2, 6.7, and 5.3 µg/L for the Phase I, Phase II, and WY2015 periods, respectively (**Table 3A-4** and **Figure 3A-8**). For WCA-2, the interior geometric mean TP concentration of 8.7 µg/L observed for WY2015 represents the seventh consecutive year that this area's mean TP concentration has been at or below 10 µg/L and is also the lowest concentration observed since WY1979 (**Figure 3A-8**). Annual geometric mean TP concentration trends throughout the interior portions of the EPA have significantly declined throughout the entire POR for all areas, except for the Refuge, as indicated by the Kendall's τ trend analysis ranging in a magnitude of change from -0.48 to -0.08 µg/L per WY (**Table 3A-4**). Based on this analysis, the Refuge interior was not significantly different throughout the POR, presumably due to the extremely high values during the 1987–1988 period and the very high interannual variance (**Figure 3A-8**). The continued decreases in TP concentration observed in WCA-2 and WCA-3 likely reflect recovery from the recent climatic extremes, improved treatment of the inflows to these areas (which is supported by similar decreases in inflow concentrations), and enhanced conditions in the impacted portions of the marsh. This includes the area downstream of the S-10 structures, which is one of the area's most highly impacted by historical phosphorus enrichment, where the quantity of discharge has been significantly reduced and the quality of the discharge has improved since STA-2 operations began.

Throughout the entire POR (i.e., WY1979-2015), 41 monitoring locations including inflow, outflow, rim, and interior monitoring stations throughout the EPA have experienced significantly declining trends (**Figure 3A-10**). The magnitude of change as indicated by the Sen's slope estimate for significantly declining trends ranged from -6.13 to -0.07 µg/L per WY. Throughout the POR, three sites were determined to have significantly increasing trends, these sites include S-5AD (Refuge Inflow), SITE-D (WCA-2 interior), and US41-25 (WCA-3 outflow) with a magnitude of change between 0.15 to 5.5 µg/L per WY. Site S-5AD is located directly downstream of the S-5A inflow pump station and was monitored from WY1994–WY2007. Annual TP geometric mean concentrations were relatively elevated for this stations ranging between 79 and 190 µg/L for the entire POR with drastic increases observed during the later years of monitoring. It should be noted that after construction and operation of the Everglades STAs, this water was routed to the STAs for treatment prior to entering the Refuge. Furthermore stations SITE-D and US41-25 observed a lower magnitude of change relative to S-5AD with 1.36 and 0.15 µg/L per WY. SITE-D, monitored between WY1979 and WY1992, was located at approximately the mid-point of the F-transect within WCA-2. In recent years, this area has experienced a recovery in TP concentrations (Julian et al., 2015) with several locations upstream of this station experiencing significantly decreasing trends (**Figure 3A-10**). Meanwhile, US41-25 is an active monitoring station that has experienced slight episodic increases in annual geometric mean TP concentrations between WY1995 and WY2015. A complete summary of trend analysis statistical results can be found in Table-3 in Appendix 3A-4 of this volume.

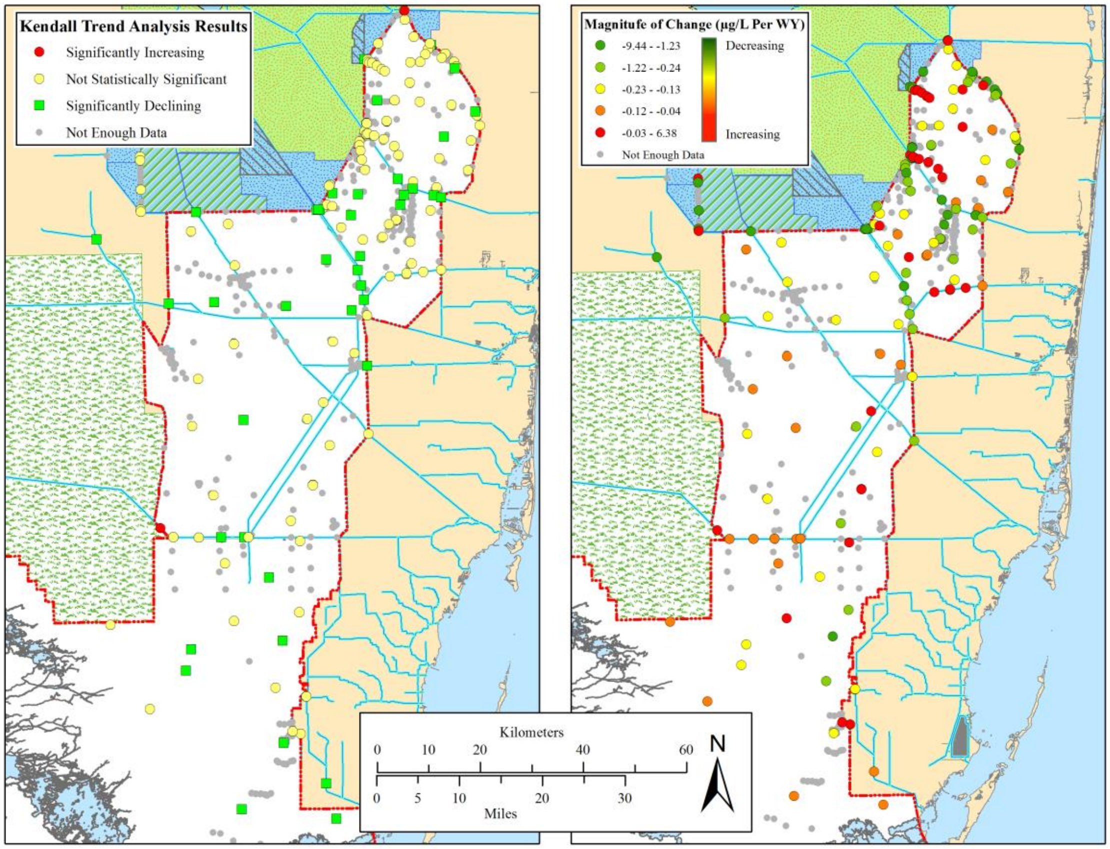

Figure 3A-10. Annual geometric mean TP trend analysis results for the entire period of record (WY1979–WY2015).

Annual geometric mean TP concentrations for individual interior marsh monitoring stations used in the assessment of the TP rule (i.e., Rule 62-302.540 F.A.C., as detailed in Appendix 3A-6 of this volume) and other ambient interior marsh monitoring stations sampled six or more times during WY2015 ranged from 2.4 µg/L (Station: P37) in some unimpacted portions of the marsh to 25.9 µg/L (Station: WCA3F1) at a WCA-2 site that is highly influenced by canal inputs. Across the entire EPA (Refuge, WCA-2, WCA-3, and ENP), 72.9 percent of the interior marsh sites exhibited annual geometric mean TP concentrations of 10.0 µg/L or less during WY2015. Interior marsh stations within the EPA experienced 13.6, 61.4, and 60.6 percent of samples with geometric mean TP concentrations less than or equal to 10 µg/L during the Baseline, Phase I, and Phase II periods, respectively. Additionally, 84.8 percent of the interior sites had annual geometric mean TP concentrations of 15.0 µg/L or less during WY2015. Interior marsh stations within the EPA experienced 20.2, 74.5, and 72.5 percent of samples with geometric mean TP concentrations less than or equal to 15 µg/L during the Baseline, Phase I, and Phase II periods, respectively. Furthermore, the percentage of stations within each region of the EPA achieve 15 µg/L, 10 µg/L, and 5 µg/L increases north-to-south (**Figures 3A-9** and **3A-11**).

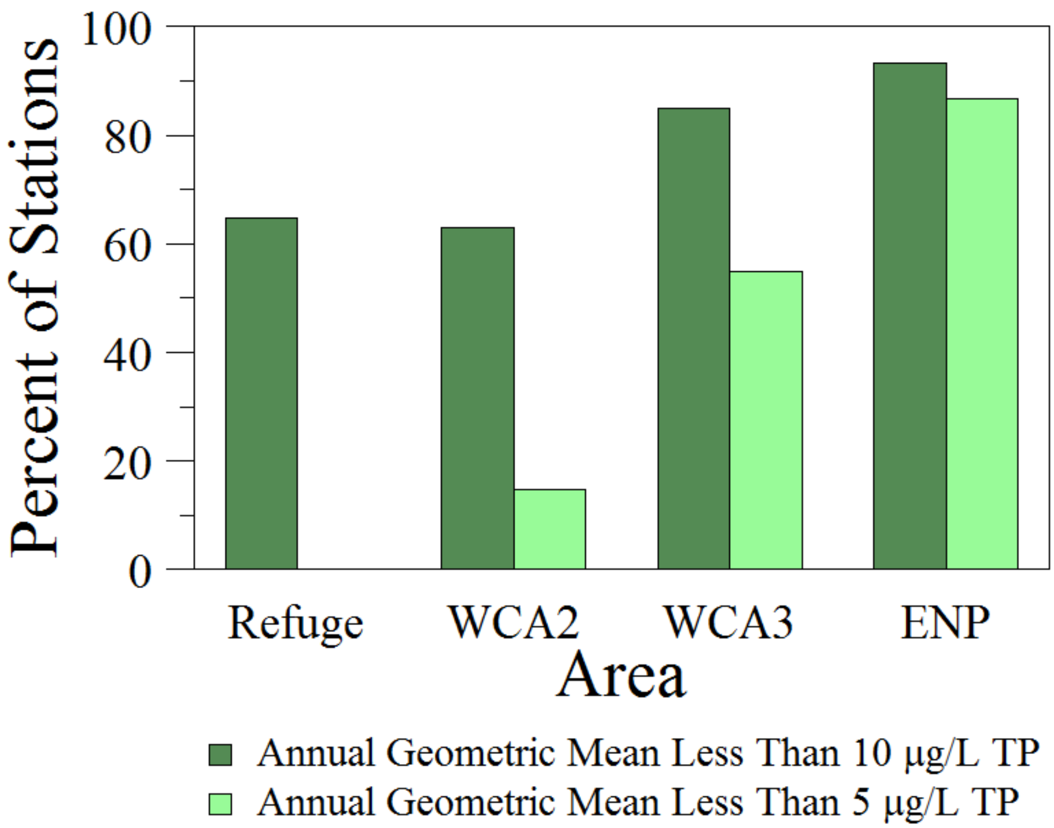

Figure 3A-11. Percentage of stations with each region of the EPA that achieved an annual geometric mean TP concentration of 10 µg/L and 5 µg/L during WY2015.

The higher percent of interior monitoring stations meeting the 10 and 15 µg/L limits observed for WY2015 reflects the continued recovery from recent climatic extremes, improved treatment of the inflows, and overall improvement in phosphorus conditions within the interior marsh due to ongoing restoration activities. Furthermore, this trend of improvement is apparent for stations used to assess the TP rule. Given the relatively constant location of interior monitoring sites in recent years, temporal comparison of statistics from individual sites can be used to distinguish changes in measured concentrations. However, it should be noted that since the existing monitoring network was not originally designed to allow results to accurately estimate the percentage of the marsh exceeding a TP concentration of 10.0 µg/L (or other thresholds), it is not appropriate to use the results for that purpose. Instead, a select group of stations have been established in recent years and identified so that comparison of TP concentrations to established threshold can be conducted.

Total Phosphorus Criterion Achievement Assessment

The TP criterion rule specifies that while the federal Settlement Agreement (Case No. 88-1886-CIV-MORENO) is in effect, compliance with the criterion in the Park will be assessed in accordance with the methodology specified in Appendix A of the Settlement Agreement using FWM TP concentrations at inflow sites instead of ambient marsh TP concentrations, as done in the other portions of the EPA. The Settlement Agreement assessments for the Park are conducted by the District and reported on a quarterly basis to satisfy other mandates and are not replicated here. The quarterly Settlement Agreement reports prepared by the District are available online at www.sfwmd.gov/toc.

In addition to establishing numeric TP criterion, Rule 62-302.540, F.A.C., also provides a four-part test to be used to determine achievement of the criterion. Each component must be achieved for a water body to be considered in compliance. Appendix 3A-6 of this volume provides results of the preliminary evaluation to assess TP criterion achievement using available data for the most recent five-year period, WY2011–WY2015, impacted TP rule station transition assessment and TP Rule POR trend analysis. As described previously, the results of this assessment were affected by data limitations in many parts of the EPA during some years caused in part by the extremely dry conditions that have prevailed throughout the area. Additionally, monitoring at nine new sites (added to the existing sites to form the TP criterion monitoring network) was not initiated until January 2007. During WY2015, 55 of the 58 TP criterion monitoring network sites had sufficient data (i.e., six or more samples and samples in the wet and dry seasons specified by the screening protocol referenced by the TP criterion rule, per Rule 62-302.540, F.A.C.) to be included in the TP criterion assessment. In contrast, only 30 of the 58 sites had a sufficient number of samples during WY2007, with less than 50 percent of the Refuge and WCA-3 monitoring sites having the minimum number of samples required for inclusion in the TP criterion assessment.

During WY2015, an assessment of impacted TP rule stations was conducted based on guidance according to subparagraph 62-302.540(4)(d)2 F.A.C. in that individual stations in networks shall be deemed to be unimpacted for purposes of determining compliance assessment with the TP rule if the five-year geometric mean is less than or equal to 10 µg/L TP and the annual geometric mean is less than or equal to 15 µg/L TP. The detailed assessment can be found in Appendix 3A-6. As a result of the assessment, no stations were identified to transition from impacted to unimpacted based on additional data available from WY2015..

The results of the WY2011–WY2015 TP criterion assessment indicate that, even with the data limitations, the unimpacted portions of each WCA passed all four parts of the compliance test (as expected) and are therefore in compliance with the 10 µg/L TP criterion. Occasionally, individual sites within the unimpacted portions of the WCAs exhibited an annual site geometric mean TP concentration above 10 µg/L, as expected, but in no case did the values from any one unimpacted site influence or result in an exceedance of the annual or long-term network limits. None of the annual geometric mean TP concentrations for the individual unimpacted sites during the WY2011–WY2015 period exceeded the 15 µg/L annual site limit.

In contrast, the impacted (i.e., phosphorus-enriched) portions of each water body failed one or more parts of the test and therefore exceeded the criteria. The impacted portions of the WCAs routinely exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively. During the WY2010–WY2014 period, numerous individual sites within the impacted areas exhibited annual geometric mean TP concentrations below the 15 µg/L annual site limit. In a few instances, the annual mean for individual impacted sites was below 10 µg/L; however, none of the impacted sites were consistently below the 10 µg/L long-term limit.

Total Phosphorus Loads

Each year, the EPA receives variable amounts of surface water inflows based on the hydrologic variability within the upstream basins. These regulated inflows contribute to the TP loading to the EPA system. **Figure 3A-12** shows five-year (WY2011–WY2015) average annual flows, TP loads, and FWM TP concentrations to STAs and diversions from inflow tributaries and across the EPA. Approximately 152 mt per year of TP was delivered from upstream sources (Lake Okeechobee, EAA Basin, C-139 Basin, L-8 Basin/Reservoir, C-51W Basin, and other Water Conservation Districts) over the last five years. About 26 mt per year of TP was delivered to the EPA after treatment by the Everglades STAs and 6 mt per year of TP was delivered to the EPA by diversion. Another 5 and 10 mt per year of TP was delivered to the EPA from the eastern and western Non-ECP basins, respectively. **Figure 3A-12** shows five-year (WY2011–WY2015) average annual flows, TP loads, and FWM TP concentrations across the EPA. These data show that there is a concentration gradient from north (five-year average annual FWM TP concentration of 37 µg/L into WCA-1) to south (five-year average annual FWM TP concentration of 9 µg/L into ENP). Data for **Figures 3A-12** and **3A-13** are presented in Appendix 3A-5, Tables 6 through 11. **Table 3A-5** provides estimates of the inflow and TP load to each portion of the EPA for WY2015. Flows and TP loads are also provided for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2014) periods for comparison.

In addition to inflow, atmospheric deposition contributes to the TP loading into the EPA. The long-term average range of TP atmospheric deposition to the WCAs is estimated between 107 and 143 mt per year. Atmospheric TP deposition rates are highly variable but not routinely monitored due to their high expense. The range [expressed spatially as 20 to 35 milligrams per square meter per year ($mg/m^2/yr$)] is based on data obtained from long-term monitoring evaluated by the District (Redfield, 2002).

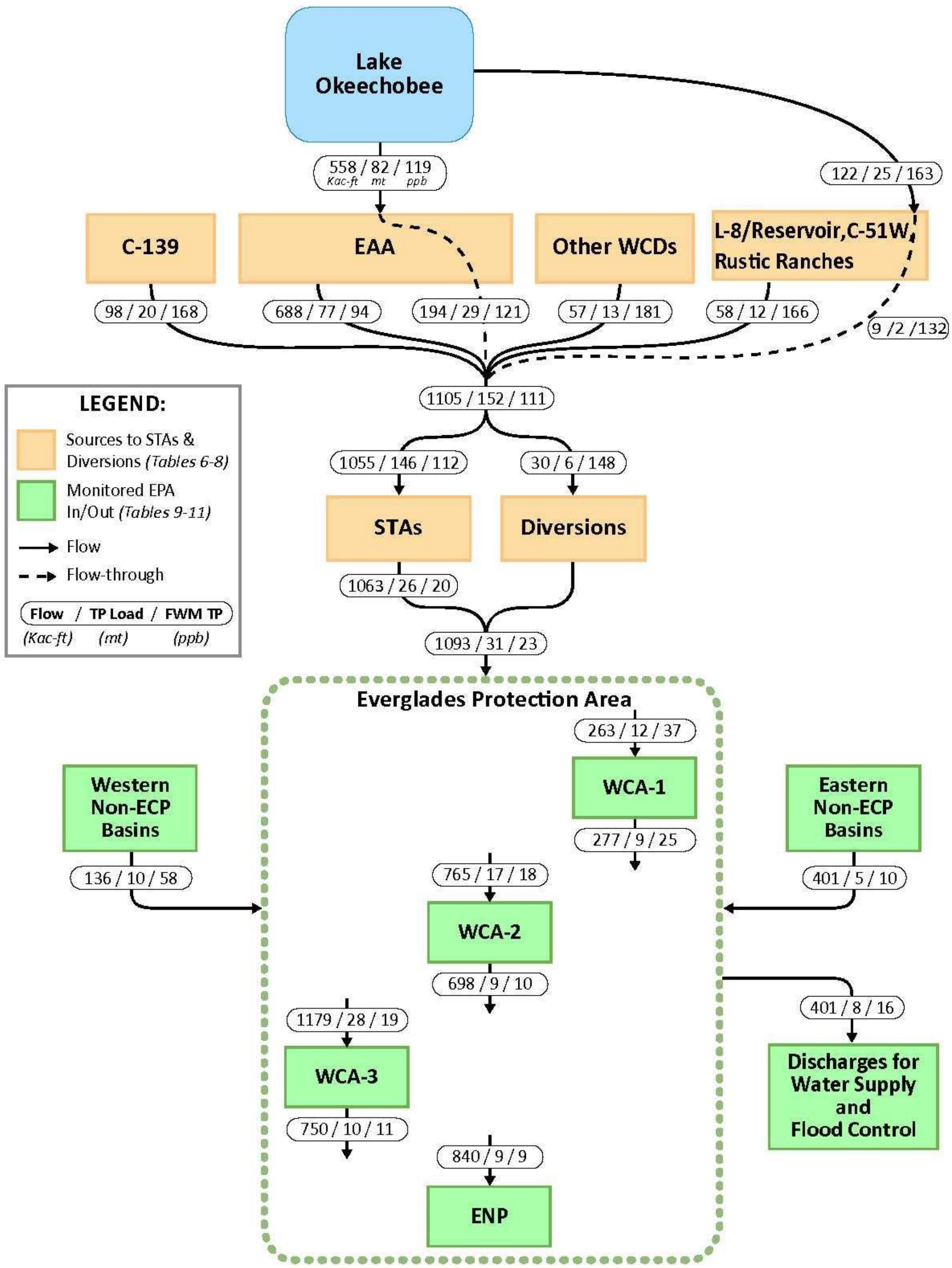

Figure 3A-12. Five-year (WY2011–WY2015) average annual flows [1,000 acre-feet (Kac-ft)], TP loads [metric tons (mt)], and flow-weighted mean (FWM) TP concentrations [µg/L, or parts per billion (ppb)] to the STAs and diversions from inflow tributaries and across the EPA. [Note: WCD=water control district; ECP=Everglades Construction Project.]

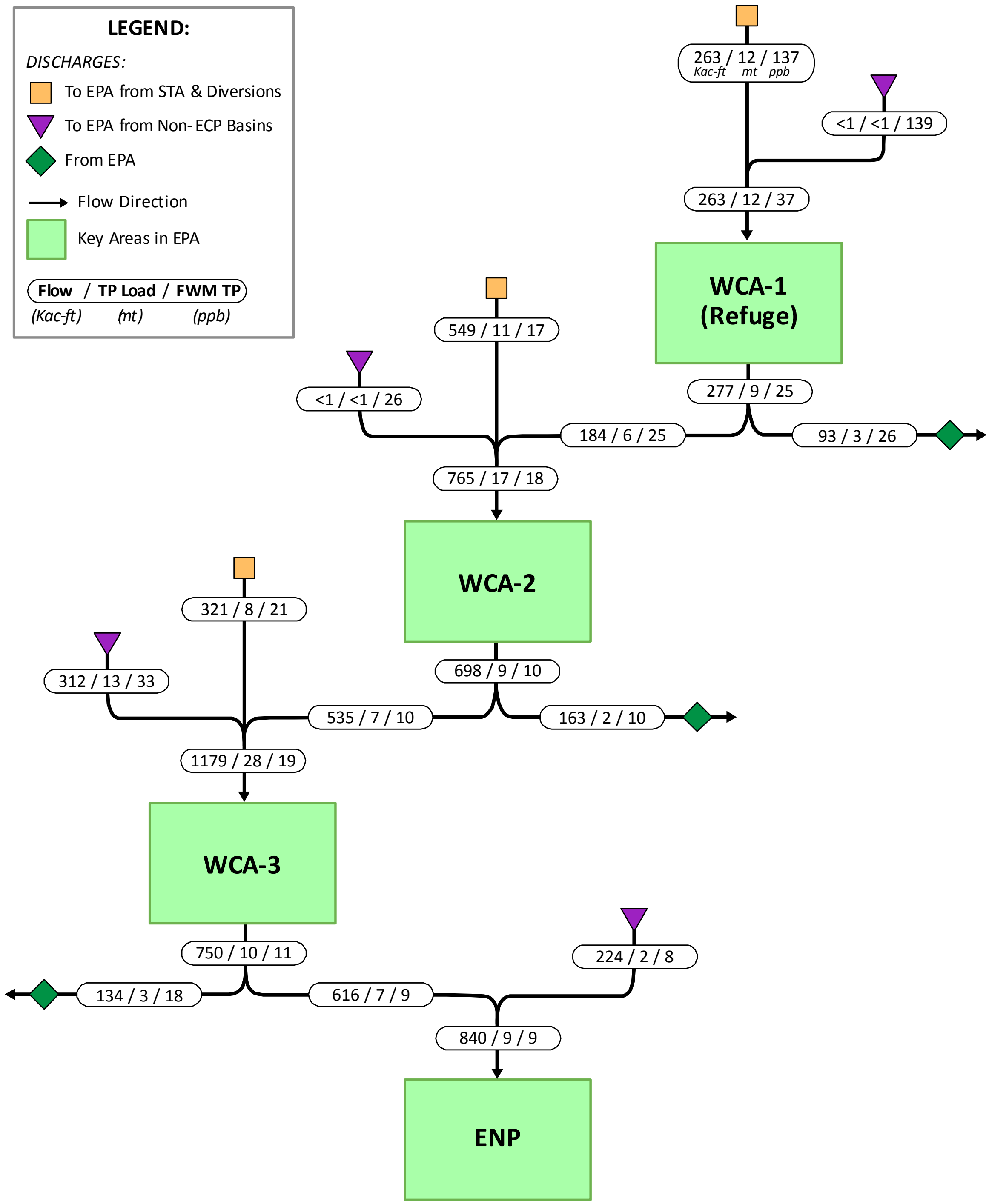

Figure 3A-13. Five-year (WY2011–WY2015) average annual flows (Kac-ft), TP loads (mt), and FWM TP concentrations (µg/L, or ppb) across the EPA. [Note: Values for each year are presented in this appendix in the 2011–2015 SFERs – Volume I, Appendix 3A-5. From EPA are discharges for water supply and flood control.]

Table 3A-5. Annual average flow, FWM TP concentrations, and TP loads in the EPA for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2014), and WY2015 periods. Mean flow, FWM TP, and TP loads for the previous five water years are also included.

	Area	Period				Last 5-WY Mean
		Baseline WY1979-1993	Phase I WY1994-2004	Phase II WY2005-2014	Current WY2015	2011-2015
Mean Annual Flow (kacre-feet)[1]	Refuge	506	647	295	245	263
	WCA-2	581	704	812	824	765
	WCA-3	1,181	1,396	1,282	1,308	1,179
	ENP	815	1,477	915	683	840
Mean Annual TP Load (kilograms)[2]	Refuge	111,436	83,977	26,035	6,025	12,118
	WCA-2	78,670	57,391	26,251	15,656	17,188
	WCA-3	108,357	84,335	44,124	33,477	27,608
	ENP	11,450	15,912	10,153	10,002	9,251
Mean Annual FWM TP (µg/L)	Refuge	186	100	71	20	37
	WCA-2	119	65	26	15	18
	WCA-3	72	49	28	21	19
	ENP	12	9	9	12	9

[1] 1 kacre-ft = 1,000 acre-feet; 1 acre-feet = 0.1233 hectare-meters
[2] 1 kilogram = 0.001 metric tons

Detailed estimates of TP loads by structure for WY2015 are presented in Appendix 3A-5 of this volume. This appendix summarizes contributions from all tributaries connecting to the EPA: Lake Okeechobee, EAA, C-139 Basin, other agricultural and urbanized areas, and Everglades STAs. In some cases, surface water inflows represent a mixture of water from several sources as it passes from one area to another before arriving in the EPA. For example, water discharged from Lake Okeechobee can pass through the EAA and then through an STA before arriving in the EPA. Similarly, runoff from the C-139 Basin can pass through STA-5/6 and STA-3/4 and then into the EAA before reaching the EPA.

As detailed in Appendix 3A-5, WY2015 annual TP loads from external surface sources to the Refuge, WCA-2, WCA-3, and ENP were 47.1 mt, with a FWM TP concentration of 21 µg/L. Another 193 mt of TP is estimated to have entered the EPA through atmospheric deposition (Redfield, 2002). Discharges from the EPA account for 8.0 mt of TP for water supply and flood control. The 47.1 mt TP load in EPA surface inflows represents a decrease of approximately 2 percent compared to WY2014 (59.6 mt). During WY2015, the lower TP loads to the EPA resulted from the reduction of external source TP loads with a decrease in flow volumes entering the EPA and improvement of STA performances. The EPA received 1,808 kacre-feet of surface water flow, which is a 14 percent decrease from WY2014 volumes (2,112 kacre-ft; Julian et al., 2015). Annual TP loads to ENP from surface water sources were 10.0 mt with a FWM TP concentration of 12 µg/L. ENP inflow loads decreased 2 percent from WY2014 (10.2 mt), due to significant decrease (39 percent) in flow surface water flow delivered to the Park in WY2015 (683 kacre-ft) compared to that previous water year (1,114 kacre-ft).

A summary of the annual flows and TP loads to each portion of the EPA for WY1979–WY2015 along with the annual averages for the Baseline, Phase I, and Phase II periods is presented in **Figure**

3A-14. The effectiveness of the BMP and STA phosphorus removal efforts is demonstrated by decreased TP loading to WCA-2 and WCA-3 during the Phase I and Phase II periods compared to the Baseline period despite increased flows (**Figure 3A-15**). The effects are less apparent in the Park, where inflow concentrations have remained near background levels and TP loading responds more directly to changes in flow and climatic conditions (**Figure 3A-15**).

The mean flow and TP loads to the EPA, especially the Refuge, during the Phase II and WY2014 periods have been highly influenced by climatic extremes, as previously discussed. The annual TP load from all sources to the Refuge was approximately 6.0 mt during WY2015, which represents a 68 percent decrease from WY2014 (18.9 mt). Surface water volume decreased 35 percent in WY2015 (245 kacre-ft) compared to WY2014 (380 kacre-ft). The FWM concentration decreased from 40 µg/L in WY2014 to 20 µg/L in WY2015. Other areas of the EPA experienced similar decreases in flow and TP load during WY2015, except for WCA-3 and ENP. WCA-2 had the lower TP inflow load during WY2015 (15.7 mt) relative to WY2014 (26.1 mt). WCA-3 showed an increase of 5 percent in TP inflow load during WY2015 (33.5 mt) relative to WY2014 (31.9 mt) although surface water inflow decreased 48 percent (WY2014: 1,425 kacre-ft, WY2015:1,308 kacre-ft). ENP experienced a decreased of 2 percent in TP inflow load during WY2015 (10.0 mt) relative to WY2014 (10.2 mt). Decreased TP loads to the Refuge in WY2015 (flow:245 kacre-ft; TP load:6.0 mt) are primarily due to performance improvements of STA-1E/1W and a decrease in flows relative to WY2014 (flow:1380 kacre-ft; TP load: 18.9 mt). Although TP loads and concentrations were reduced relative to the Baseline period, more monitoring is needed before the effects of Phase II BMP and STA optimization projects can be accurately assessed.

As shown in Appendix 3A-5, Table 6, there was a significant increase of flow from Lake Okeechobee to the Everglades STAs for WY2015 (585.3 kac-ft) compared with WY2011–WY2015 (five-year average; 203 kac-ft). The TP loads increased proportionally to 87.6 mt in WY2015 compared with WY2011–WY2015 (five-year average; 30.2 mt), as shown in Appendix 3A-5, Table 7. The WY2015 increase of water from Lake Okeechobee to the Everglades STAs appears improved overall outflow FWM TP concentrations of STAs (17 µg/L, as shown in Appendix 3A-5, Table 8). Overall, the outflow FWM TP concentration of 17 µg/L in WY2015 is the lowest during the WY2011–WY2015 period. Reduced FWM TP concentrations from outflow of the STAs partially explained the decreasing concentrations into the Refuge and WCA-2 in WY2015.

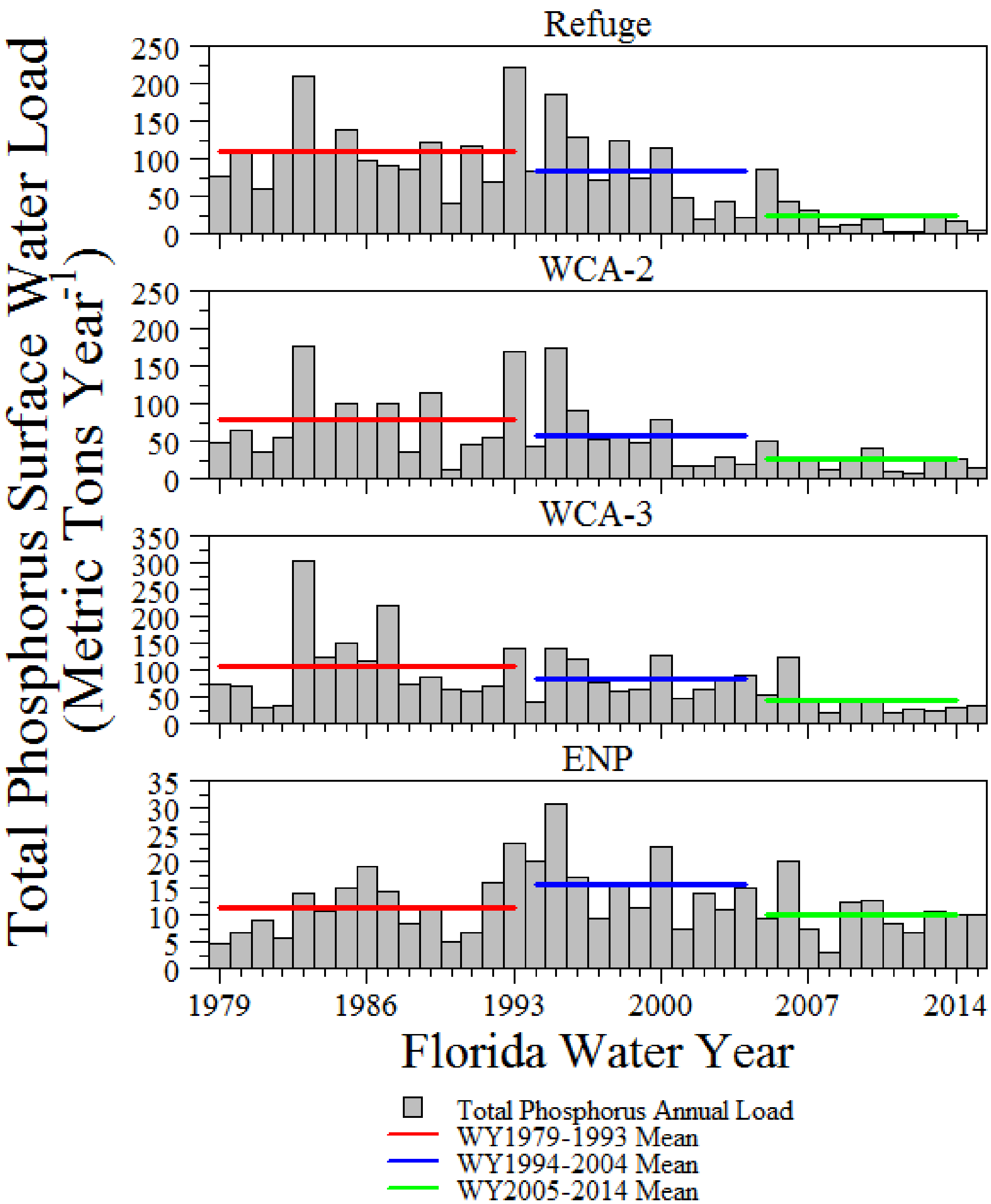

Figure 3A-14. Annual inflow TP load for the Refuge, WCA-2, WCA-3, and ENP from WY1979–WY2015. The horizontal lines indicate the mean annual loads and flows for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2014) periods.

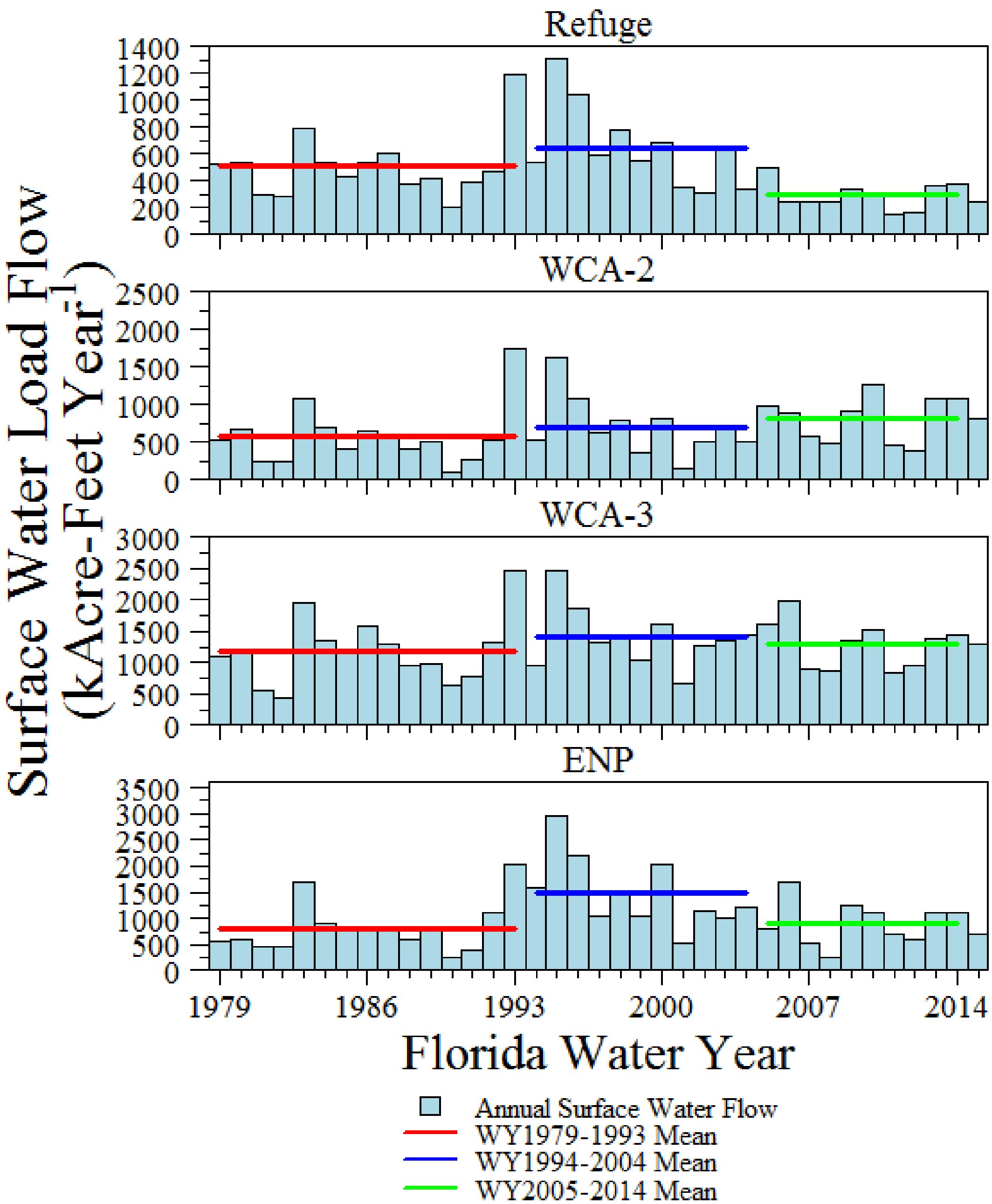

Figure 3A-15. Annual inflow surface water flow for the Refuge, WCA-2, WCA-3, and ENP from WY1979–WY2015. The horizontal lines indicate the mean annual loads and flows for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2014) periods.

Orthophosphate Concentrations

Orthophosphate (OP) is an inorganic, soluble form of phosphorus readily utilized by biological organisms and, therefore, has the greatest and most rapid effect on the Everglades ecosystem. During WY2015, geometric mean OP concentrations at inflow, interior, and outflow stations in all areas within the EPA were lower than concentrations observed during the Baseline, Phase I, and Phase II periods (**Figure 3A-16** and **Table 3A-6**).

Since WY1979, OP concentrations have drastically declined for inflows into the EPA (**Figure 3A-16**). During WY2015, geometric mean OP concentrations at inflow stations ranged from 2.0 µg/L in WCA-3 to 1.0 µg/L in the Park. Inflow geometric mean OP concentrations have declined for all areas. The Refuge has experienced the greatest reduction in OP concentrations between Baseline and Phase I periods experiencing 58.2 µg/L and 17.0 µg/L, respectively. This trend continued in Phase II and WY2015 with geometric mean concentrations of 4.6 µg/L and 1.2 µg/L. Geometric mean OP concentrations at WCA-2 inflow regions during the Baseline, Phase I, Phase II, and WY2015 were 36.7, 14.9, 2.4, and 1.2 µg/L, respectively. Geometric mean OP concentrations at WCA-3 inflow regions during the Baseline, Phase I, Phase II, and WY2015 were 11.7, 10.0, 2.7, and 2.0 µg/L, respectively. ENP has by far experienced the lowest geometric mean OP concentrations in the EPA with inflow geometric mean OP concentrations during the Baseline, Phase I, Phase II, and WY2015 of 2.7, 2.7, 1.3, and 1.0 µg/L, respectively.

Geometric mean concentrations for interior regions of the EPA have fluctuated between periods for the Refuge and WCA-2. Geometric mean OP concentrations within the Refuge interior during the Baseline, Phase I, Phase II, and WY2015 were 1.5, 1.5, 1.9, and 1.0 µg/L, respectively. Geometric mean OP concentrations within WCA-2 interior during the Baseline, Phase I, Phase II, and WY2015 were 4.0, 4.3, 1.7, and 1.2 µg/L, respectively. WCA-3 and ENP have experienced an overall decline in geometric mean OP concentration throughout the periods of assessment. Geometric mean OP concentrations within WCA-3 interior during the Baseline, Phase I, Phase II, and WY2015 were 1.8, 1.7, 1.5, and 1.1 µg/L, respectively. Geometric mean OP concentrations within ENP interior during the Baseline, Phase I, Phase II, and WY2015 were 2.6, 2.5, 1.4, and 1.0 µg/L, respectively

Since WY2007, annual geometric mean OP concentrations for interior locations have been low, with concentrations being less than 2.0 µg/L for all areas (**Figure 3A-16**). Sustained reduction of OP concentrations for both inflow and interior sites over the past several water years shows the continued recovery from the recent extreme climatic events, preferential removal of OP by the STAs, and effects of restoration activities to improve the overall phosphorus conditions in the interior marsh areas.

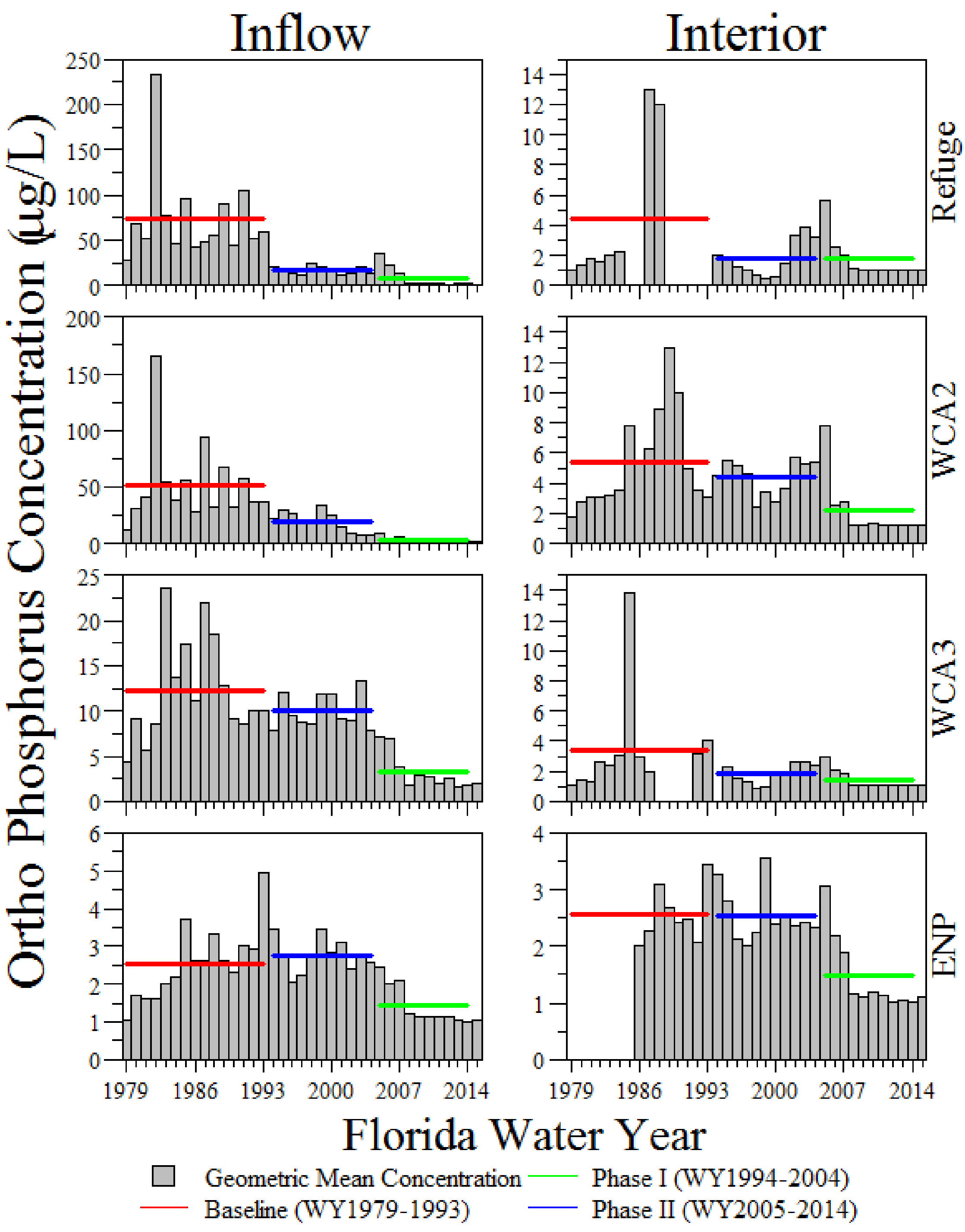

Figure 3A-16. Annual geometric mean Ortho Phosphorus concentrations (µg/L) for inflow (left panel) and interior (right panel) areas of the Refuge, WCA-2, WCA-3, and ENP from WY1979–WY2015. Bars indicate geometric mean when flow, dash-line indicates geometric mean irrespective of flow. The horizontal lines indicate the mean annual geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2014) periods. [Note: Areas with no bars indicate data gaps.]

Table 3A-6. Summary statistics of orthophosphate concentrations (μg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2014), and WY2015 periods.

Region	Class	WY Period	Sample Size	Geometric Mean	Geometric Standard Deviation	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	413	58.2	7.5	76.0	<2.0	849
		1994-2004	1581	17.0	5.7	15.0	<2.0	220
		2005-2014	1016	4.7	6.5	2.0	<2.0	489
		2015	140	1.2	1.7	1.0	<2.0	9
	Interior	1979-1993	381	1.5	2.8	1.0	<2.0	278
		1994-2004	1507	1.5	2.6	1.0	<2.0	10
		2005-2014	3142	1.9	3.1	1.0	<2.0	506
		2015	369	1.0	1.2	1.0	<2.0	3
	Outflow	1979-1993	334	23.0	7.7	32.5	<2.0	1290
		1994-2004	307	15.2	5.6	13.0	2.0	217
		2005-2014	226	3.5	5.6	2.0	<2.0	461
		2015	26	1.1	1.5	1.0	<2.0	3
	Rim	1979-1993	96	33.5	6.7	39.5	<2.0	408
		1994-2004	485	27.8	6.3	34.0	<2.0	190
		2005-2014	306	38.2	7.2	46.5	2.0	544
		2015	---	---	---	---	---	---
WCA-2	Inflow	1979-1993	460	36.7	7.1	44.0	<2.0	1290
		1994-2004	722	14.9	5.7	13.0	2.0	217
		2005-2014	940	2.4	3.9	2.0	<2.0	190
		2015	156	1.2	1.8	1.0	<2.0	11
	Interior	1979-1993	2007	4.0	5.9	2.0	<2.0	1967
		1994-2004	1817	4.3	5.5	4.0	<2.0	960
		2005-2014	2373	1.7	2.7	1.0	<2.0	186
		2015	280	1.2	1.9	1.0	<2.0	15
	Outflow	1979-1993	587	6.1	5.6	5.0	<2.0	345
		1994-2004	435	5.4	4.0	5.0	2.0	74
		2005-2014	512	1.6	2.5	1.0	<2.0	31
		2015	55	1.3	1.9	1.0	<2.0	6
WCA-3	Inflow	1979-1993	1276	11.7	7.0	13.0	<2.0	596
		1994-2004	2159	10.0	5.5	9.0	2.0	265
		2005-2014	2656	2.7	4.5	2.0	<2.0	153
		2015	396	2.0	4.4	1.0	<2.0	228
	Interior	1979-1993	592	1.8	3.2	1.0	<2.0	142
		1994-2004	1922	1.7	2.9	2.0	<2.0	85
		2005-2014	2025	1.5	2.0	1.0	<2.0	39
		2015	179	1.1	1.6	1.0	<2.0	12
	Outflow	1979-1993	1348	2.8	3.3	2.0	<2.0	116
		1994-2004	1434	2.8	2.7	2.0	2.0	23
		2005-2014	3168	1.3	1.9	1.0	<2.0	23
		2015	334	1.0	1.2	1.0	<2.0	2
ENP	Inflow	1979-1993	1633	2.7	3.0	2.0	<2.0	77
		1994-2004	1897	2.7	2.7	2.0	2.0	49
		2005-2014	4827	1.3	1.7	1.0	<2.0	23
		2015	590	1.0	1.2	1.0	<2.0	2
	Interior	1979-1993	509	2.6	2.7	2.0	2.0	63
		1994-2004	935	2.5	2.5	2.0	2.0	45
		2005-2014	1097	1.4	2.0	1.0	<2.0	19
		2015	125	1.1	1.4	1.0	<2.0	3

Total Nitrogen Concentrations

Elevated concentrations of nitrogen in freshwater ecosystems are of concern due to the role of nitrogen in eutrophication of freshwater systems, the effect on the oxygen content of receiving waters, and its potential toxicity to aquatic invertebrate and vertebrate species (Kadlec and Wallace, 2009; Saunders and Kalff, 2001). However, the EPA and the greater Everglades ecosystem in general is a phosphorus-limited system, which means the growth of algae and macrophytes are limited by the quantity of the phosphorus input into the system. When nitrogen is limited, biota can offset this nitrogen limitation through fixation of atmospheric N_2 (Noe et al., 2001).

One of the primary objectives of this chapter is to document temporal changes in TN concentrations across the EPA using long-term geometric means concentrations. Unlike TP, the concentration of TN in surface waters is not measured directly but is calculated as the sum of total Kjeldahl nitrogen (TKN; organic nitrogen + ammonia) and nitrite plus nitrate (NO_3 + NO_2). The TN values for this chapter were calculated only for those samples for which both TKN and NO_3 + NO_2 results were available. **Table 3A-9** provides a summary of the TN concentrations measured in the different portions of the EPA during the Baseline, Phase I, and Phase II periods, as well as WY2015.

As in previous years, TN concentrations during WY2015 exhibited a general north-to-south spatial gradient across the EPA (**Figure 3A-16**). This gradient likely reflects the higher concentrations associated with discharges to the northern portions of the system from agricultural areas and Lake Okeechobee. A gradual reduction in TN concentrations results from the assimilative processes in the marsh as water flows southward. The north-to-south gradient is apparent for inflow regions within the EPA with the highest geometric mean TN concentrations being observed in the Refuge (1.8 mg/L), followed by WCA-2 (1.6 mg/L), WCA-3 (1.4 mg/L), and ENP inflows (1.0 mg/L). Interior geometric mean TN concentrations were reduced relative to inflow concentration within each region of the EPA most likely due to marsh assimilation. During WY2015, interior concentrations generally followed the north-to-south gradient with WCA-2 experiencing the highest geometric mean TN concentration of 1.5 mg/L, followed by the Refuge (1.1 mg/L), WCA-3 (1.3 mg/L), and ENP (1.0 mg/L). In interior portions of the EPA, biota (i.e., bacteria, algae, macrophytes) are generally highly limited by phosphorus but may become nitrogen-limited in areas enriched with P, such as areas in close proximity to canals and impacted areas (Noe et al., 2001). Therefore, assimilation of TN within WCA-2 marsh could be limited due to the relatively large portion of impacted areas (i.e., high phosphorus concentration). Since the implementation and enforcement of BMPs, changes in water management and optimization of the STAs, the marsh condition within WCA-2 has improved. This is apparent as indicated by marsh phosphorus concentrations (see above) and the TP rule assessment (Appendix 3A-6) within WCA-2. Improvement of the marsh condition is also apparent in terms of interior geometric mean TN concentrations within WCA-2, with a steady decline in TN concentrations observed throughout the assessment periods (**Table 3A-9**). This improvement is not just isolated to WCA-2 but the entire EPA.

Table 3A-9. Summary statistics of total nitrogen (TN) concentrations in milligrams per liter (mg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2014), and WY2015 periods.

Region	Class	Period	Sample Size	Geometric Mean	Geometric Standard Deviation	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	406	5.0	3.3	5.2	0.5	18.7
		1994-2004	1108	2.5	2.5	2.4	0.3	54.8
		2005-2014	401	2.0	2.1	2.1	0.7	5.4
		2015	62	1.7	1.8	1.8	1.0	2.4
	Interior	1979-1993	378	2.4	2.5	2.3	0.7	36.7
		1994-2004	1102	1.1	1.5	1.1	0.5	9.5
		2005-2014	1502	1.2	1.5	1.2	0.6	8.7
		2015	262	1.1	1.5	1.1	0.6	3.0
	Outflow	1979-1993	314	2.7	2.7	2.6	0.7	22.8
		1994-2004	274	1.9	2.3	1.8	0.7	6.4
		2005-2014	170	1.5	1.8	1.4	0.7	6.3
		2015	26	1.4	1.5	1.3	1.1	2.1
	Rim	1979-1993	96	2.9	2.7	2.8	0.8	10.9
		1994-2004	449	2.4	2.4	2.3	0.3	9.7
		2005-2014	173	2.2	2.2	2.1	1.0	8.2
		2015	46	1.6	1.6	1.6	1.1	2.3
WCA-2	Inflow	1979-1993	446	3.2	2.9	3.3	0.5	22.8
		1994-2004	537	2.4	2.3	2.4	0.7	6.4
		2005-2014	576	2.0	2.0	2.0	0.7	6.3
		2015	83	1.6	1.7	1.6	1.0	2.3
	Interior	1979-1993	1994	2.6	2.6	2.5	0.1	104.1
		1994-2004	1526	1.9	2.1	2.0	0.1	16.7
		2005-2014	1382	1.9	1.9	2.0	0.7	4.8
		2015	168	1.5	1.7	1.6	1.0	2.9
	Outflow	1979-1993	581	2.2	2.2	2.2	0.9	7.0
		1994-2004	433	1.6	1.8	1.6	0.3	4.1
		2005-2014	498	1.6	1.7	1.7	0.7	3.5
		2015	55	1.5	1.6	1.5	1.0	2.6
WCA-3	Inflow	1979-1993	1265	2.2	2.4	2.1	0.3	10.8
		1994-2004	1341	1.8	2.1	1.6	0.4	7.8
		2005-2014	1332	1.5	1.7	1.5	0.9	6.1
		2015	191	1.4	1.5	1.4	1.0	2.0
	Interior	1979-1993	575	1.9	2.2	1.9	0.4	10.0
		1994-2004	1433	1.2	1.6	1.2	0.1	9.0
		2005-2014	1096	1.3	1.6	1.3	0.6	4.0
		2015	68	1.3	1.5	1.3	0.8	2.0
	Outflow	1979-1993	1113	1.5	1.9	1.5	0.2	14.9
		1994-2004	949	1.1	1.5	1.1	0.3	4.1
		2005-2014	2655	1.2	1.5	1.2	0.5	7.1
		2015	313	1.2	1.5	1.3	0.8	4.7
ENP	Inflow	1979-1993	1446	1.3	1.9	1.4	0.1	14.9
		1994-2004	1217	0.9	1.5	1.0	0.3	3.6
		2005-2014	4134	1.1	1.4	1.0	0.5	7.1
		2015	569	1.0	1.4	0.9	0.4	4.7
	Interior	1979-1993	567	1.3	2.1	1.4	0.3	80.9
		1994-2004	940	1.1	1.7	1.1	0.3	5.7
		2005-2014	666	1.0	1.5	1.0	0.0	7.7
		2015	57	1.0	1.4	1.1	0.5	1.9

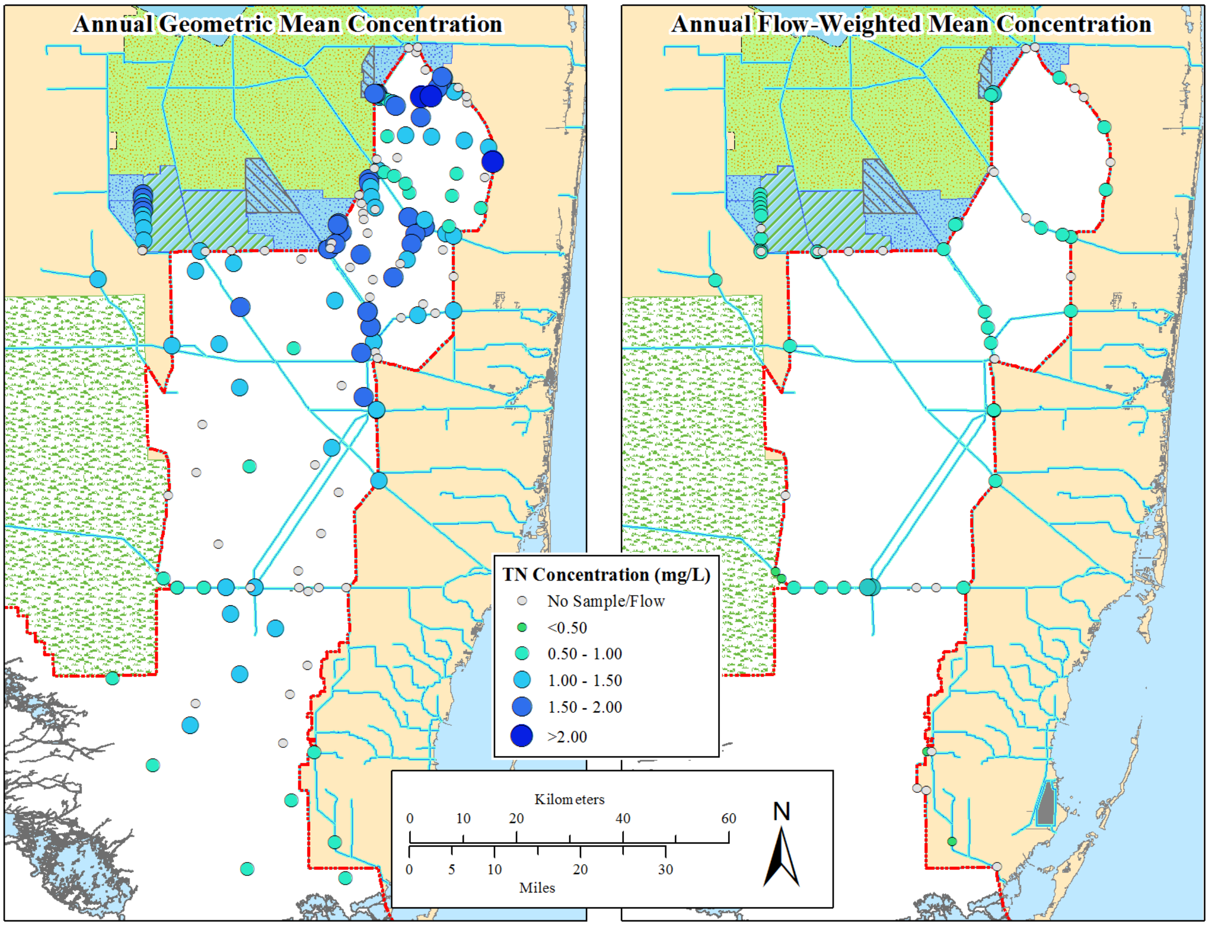

Figure 3A-16. Annual geometric mean total nitrogen (TN) concentrations for all classifications (left panel) and annual FWM TN concentrations at water control structures (right panel) for WY2015 at stations across the EPA.

Annual geometric mean TN concentrations have significantly declined since WY1979 for inflow and interior regions of the EPA as indicated by both **Table 3A-9** and **Figure 3A-16**. Further the magnitude of change was greatest for the Refuge inflows with -0.14 mg/L per WY across as 36 year POR (**Table 3A-9**). Further evidence of this decline is apparent as indicated by the trend analysis in which interior and inflow regions for all compartments of the EPA declined significantly (**Table 3A-10**). It should also be noted that the period prior to this data gap concentrations were elevated relative to geometric mean concentrations after this period. The low TN concentrations observed during WY2015 and the decreasing concentrations during the relatively recent history (i.e., WY2005–present) may be the result of improved nutrient removal effectiveness of the STAs, especially during low water conditions. As previously described (Payne et al., 2011; Julian et al. 2014; Julian et al. 2015), a strong relationship between interior station TN and TOC within the EPA is present**.** This relationship indicates that the dominant source of the TN measured within the marsh is the organic material that naturally occurs in abundance in the wetland and enters the marsh from the oxidized sediments in the EPA. Additionally, relatively low observed NO_3 + NO_2 concentrations provides support to this conclusion, indicating that inorganic forms of nitrogen from anthropogenic sources to the EPA are relatively small and are not expected to pose a significant risk to the water quality and marsh condition within the EPA.

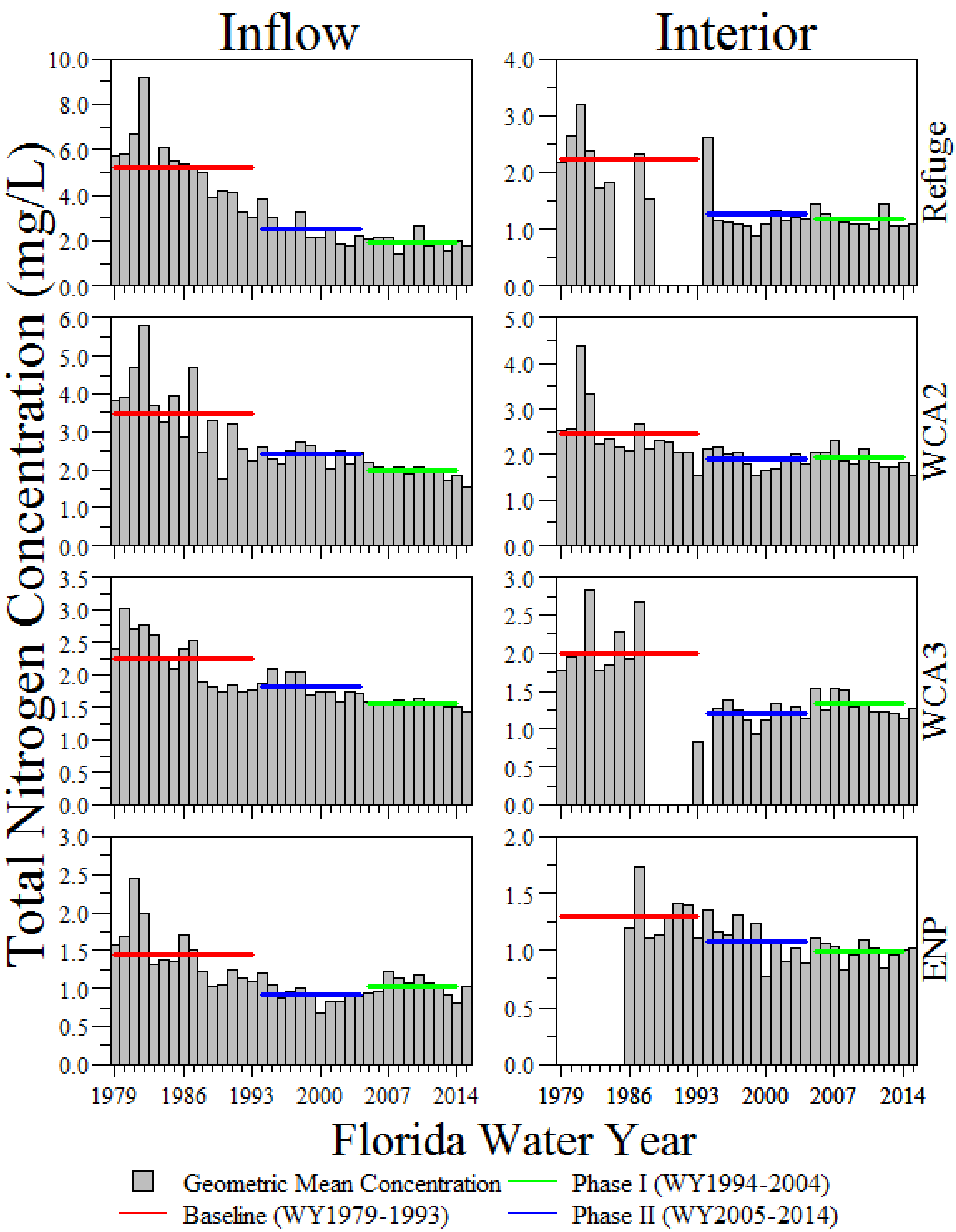

Figure 3A-17. Annual geometric mean TN concentrations (mg/L) for inflow (left) and interior (right) areas of the Refuge, WCA-2, WCA-3, ENP from WY1979–WY2015. Bars indicate geometric mean when flow; dashed line indicates geometric mean irrespective of flow. Horizontal lines indicate the mean annual geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2014) periods. [Note: Areas with no bars indicate data gaps.]

Table 3A-10. Kendall's τ annual geometric mean TN concentration trend analysis results for each region's inflow and interior classification within the EPA for the entire POR (WY1979–WY2015). Statistically significant ρ-values are italicized.

Area	Class	POR (WY1979–WY2015) Kendall's τ	ρ-value	Sen's Slope Estimate[1]
Refuge	Inflow	-0.80	*<0.01*	-0.14
	Interior	-0.51	*<0.01*	-0.03
WCA-2	Inflow	-0.71	*<0.01*	-0.06
	Interior	-0.52	*<0.01*	-0.02
WCA-3	Inflow	-0.76	*<0.01*	-0.03
	Interior	-0.36	*<0.01*	-0.02
ENP	Inflow	-0.49	*<0.01*	-0.02
	Interior	-0.53	*<0.01*	-0.01

[1] Expressed as mg/L per WY

Total Nitrogen Loads

Regulated inflows significantly contribute to the loading of TN to the EPA system. Estimates of the TN load and FWM TN concentrations to each portion of the EPA for the Baseline, Phase I, and Phase II periods and WY2015 is presented in **Table 3A-11** and **Figure 3A-18.**

Table 3A-11. Mean FWM TN concentrations and TN loads to the EPA for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2014), and WY2015 periods.

	Area	Period Baseline WY1979-1993	Phase I WY1994-2004	Phase II WY2005-2014	Current WY2015	Last 5-WY Mean 2011-2015
Mean Annual TN Load (kilograms)[2]	Refuge	3,717,807	7,207,024	2,792,095	1,653,817	1,688,123
	WCA-2	2,710,058	2,296,227	2,029,646	1,642,485	1,693,639
	WCA-3	3,880,250	3,412,542	2,567,080	2,335,814	2,256,970
	ENP	1,111,962	1,600,330	1,098,463	825,906	912,074
Mean Annual FWM TN (mg/L)	Refuge	6.20	9.75	7.75	5.46	5.70
	WCA-2	4.13	2.67	2.03	1.62	1.85
	WCA-3	2.71	1.96	1.62	1.45	1.57
	ENP	1.02	0.85	0.94	1.15	0.94

[2] 1 kilogram = 0.001 metric tons

In addition to inflow, atmospheric deposition contributes to the TN loading into the EPA. Atmospheric deposition is an important source of nutrients to oligotrophic ecosystems, furthermore meteorological conditions of South Florida are ideal for atmospheric deposition in that rainfall can scavenge aerosolized nitrogen from the atmosphere (Sutula et al., 2001). Atmospheric deposition rates can be highly variable ranging from approximately 0.005 g/m^2/yr N in remote areas to > 2 g/m^2/yr N in urban areas (Galloway et al., 2004). Since atmosphere TN deposition is highly variable and very expensive to monitor, routine monitoring is not conducted. Inglett et al. (2011) reported a TN deposition rate to the Everglades of 0.48 g/m^2/yr N. This atmospheric deposition estimate does not address the influence of traffic density of the highways near or transecting the EPA (i.e., I-75, US-41, SR-27, etc.). Motor vehicle traffic is a very important source of atmospheric deposition of NOx and is influenced by traffic density (Jimenez et al., 2000). However with improved mileage mandated by the USEPA, the NOx emission rate will be potentially reduced.

Annual TN loads from surface water sources, including internal transfers within the EPA (i.e., Refuge to WCA-2 and WCA-2 to WCA-3) were 5,632 mt (5,632,116 kilograms per year (kg/yr)], with a FWM TN concentration of 1.93 mg/L during WY2015. Using the estimated TN deposition rate provided by Inglett et al. (2011), the northern portion of the EPA (i.e., Refuge, WCA-2, and WCA-3) can potentially receive up to 1,677 metric tons per year (mt/yr) of TN (1,676,922 kg/yr) from atmospheric deposition. In WY2015, discharges from the northern EPA account for 2,557 mt/yr (2,557,129 kg/yr) of TN, with a FWM TN concentration of 1.35 mg/L. The difference between total inflow and outflow load (1,565 mt TN, respectively) indicates that uptake and assimilation of nitrogen is occurring within the natural communities of the EPA, even though the surface water load is greater than the atmospheric deposition load. In comparison to last water years TN load (8,063 mt), WY2015 experienced 23 percent decrease in TN inflow load. This decrease is most likely was due to the decrease in surface water flows and atmospheric inputs.

During WY2015, annual TN loads from surface waters to ENP were 826 mt (825,906 kg/yr), with a FWM TN concentration of 1.15 mg/L. Based on the atmospheric deposition rate provided by Inglett et al. (2011), ENP can potentially receive up to 2,987 mt/ yr of TN (2,986,506 kg/yr) from atmospheric deposition. Since the last water year, ENP observed a 13 percent increase in TN surface water inflow loads, while flows were lower during WY2015 relative to WY2014; this increase could be attributed to operational changes to the system.

As stated previously, mean flow and load to the EPA have been highly influence by climate extremes in past years. The annual TN load to the Refuge was 1,653 mt during WY2015, representing a 22 percent decrease in TN inflow compared to WY2014 (2,416 mt). This trend is consistent for WCA-2 and WCA-3. WCA-2 received 1,642 mt during WY2015, representing a 32 percent decrease in TN inflow load compared to WY2014 (2,418 mt). WCA-3 received 2,336 mt during WY2015, representing a 16 percent decrease in TN inflow load from the previous water year (2,767 mt).

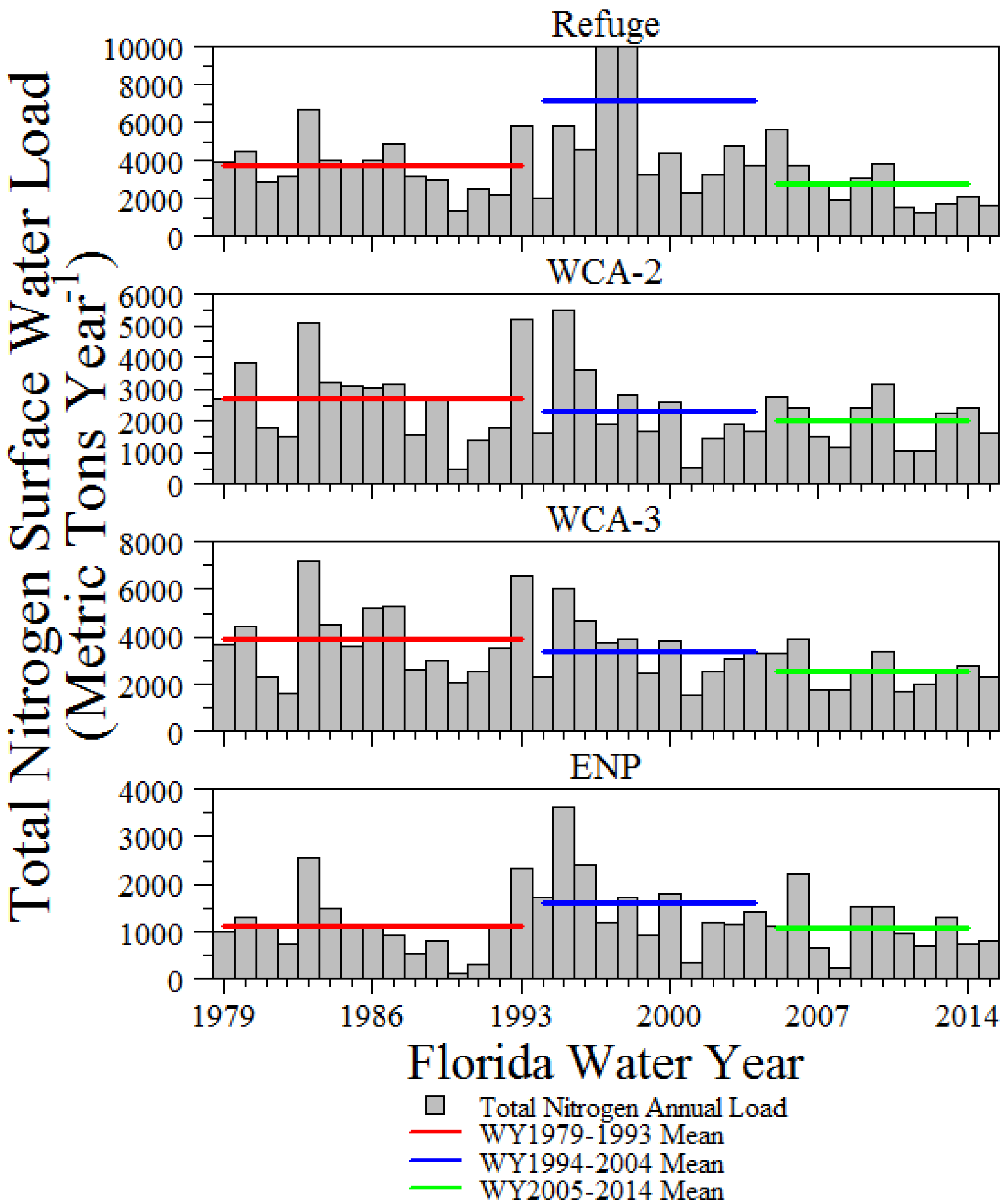

Figure 3A-18. Annual inflow TN loads for the Refuge, WCA-2, WCA-3 and ENP from WY1979–WY2015. Horizontal lines indicate the mean annual loads and flows for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2014) periods. [Note that during WY1997 and WY1998, the Refuge annual TN load reached 32,838 and 12,207 mt, respectively (outside the current scale).]

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